

Fig 1: System Layers

8. Functional Applications
7. Cellular Automata (CA) Simulations
6. Multi-Agent System (MAS) and Intelligent Mobile Software Agents (IMSA)
5. Omni-Nodal Evolutionary Artificial Neural Network (EANN)
4. Dynamic Distributed Object Relational Database Management System (ORDbMS)
3. Flexible Mobile Grid Computing Architecture in Dynamic Clusters
2. Distributed Mobile Robotic System (MRS) for Mobile Robotic Agents (MRAs)
1. Second-order Synthetic Hybrid Control System (HCS) for Mobile Robotic Agents (MRAs)

Fig 2: MRA Synthetic Hybrid Control System Architecture

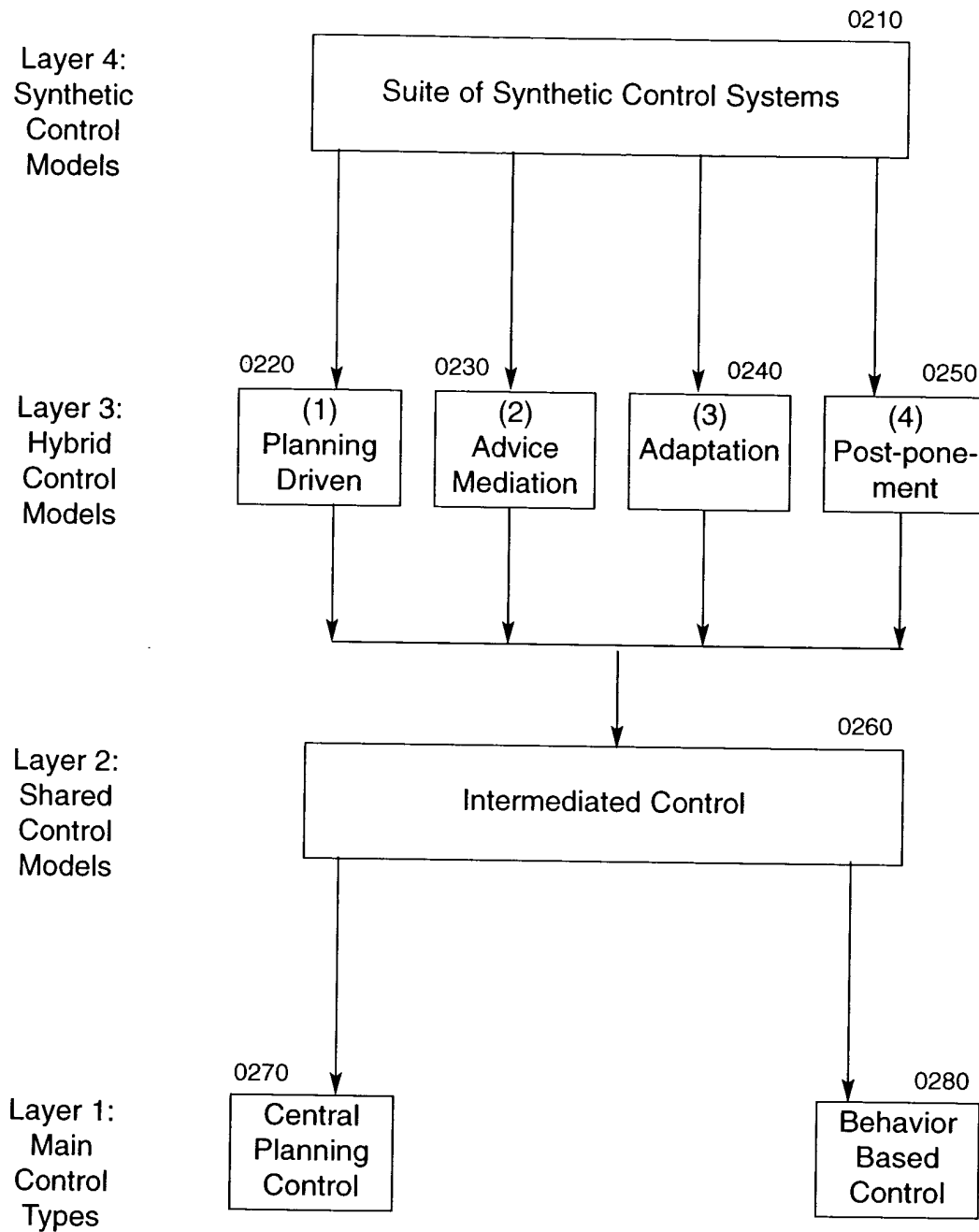


Fig 3: Dynamic Database Organization

| Modular Architecture Type | One Unit | Distributed Network | Mobility |
|--|--|---|---|
| MRAs in MRS | Hardware agent ORDb data organization | Distributed comput- ers (Data manage- ment within network) Sharing ORDBs (sharing data organi- zation functions) | Mobile robotic agents with chang- ing spatial positions |
| IMSAs in MAS | Software agents that analyze, decide, and negotiate | Mobile groups of interacting software agents | Limited range of IMSA interactions within wireless mobile robotic agent network |
| Evolutionary Artificial Neural Networks | Computation resource management | Continuous restructuring of network grid to maximize computation power | Wireless mobile grid of flexible network rewiring as it adapts to environment |

Fig 4: Identifying MRA Locations With Sensors

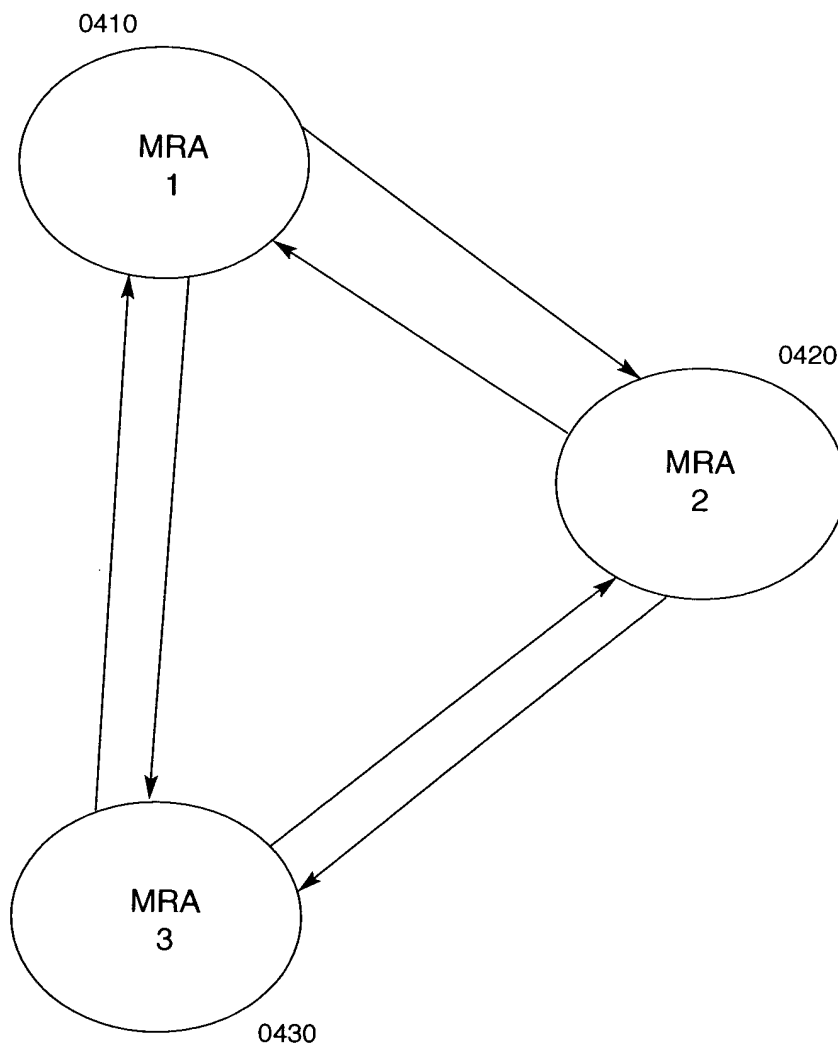
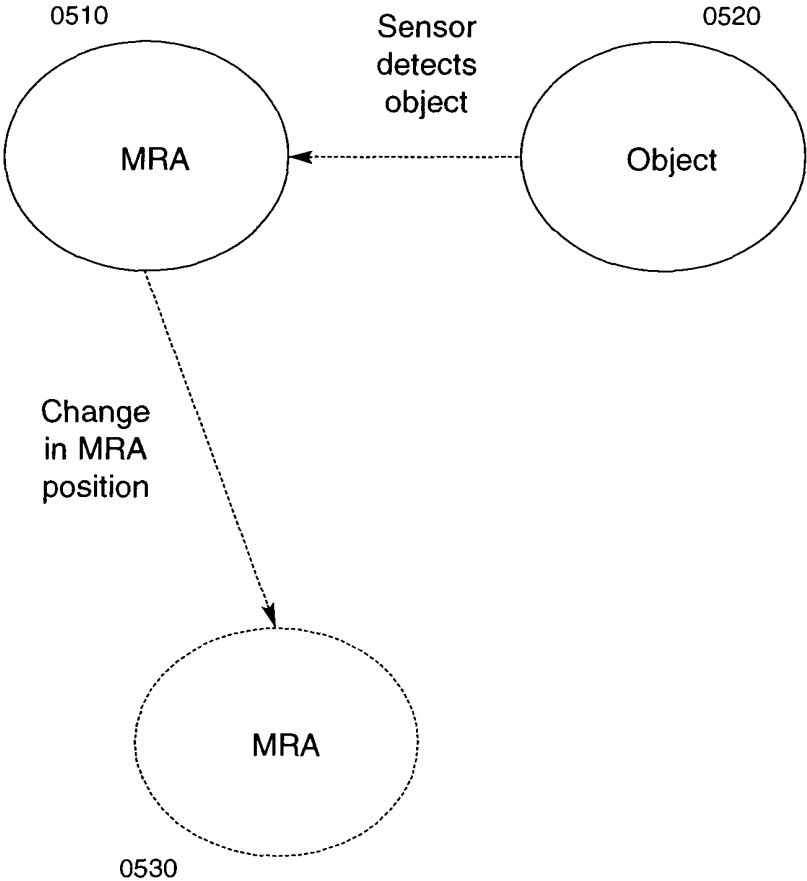


Fig 5: Assessing Environmental Situation and Coordinating Change in MRA State



**Fig 6: Metacomputing Model for Distributed MRS:
Flexible Mobile Grid Architecture in Dynamic Clusters**

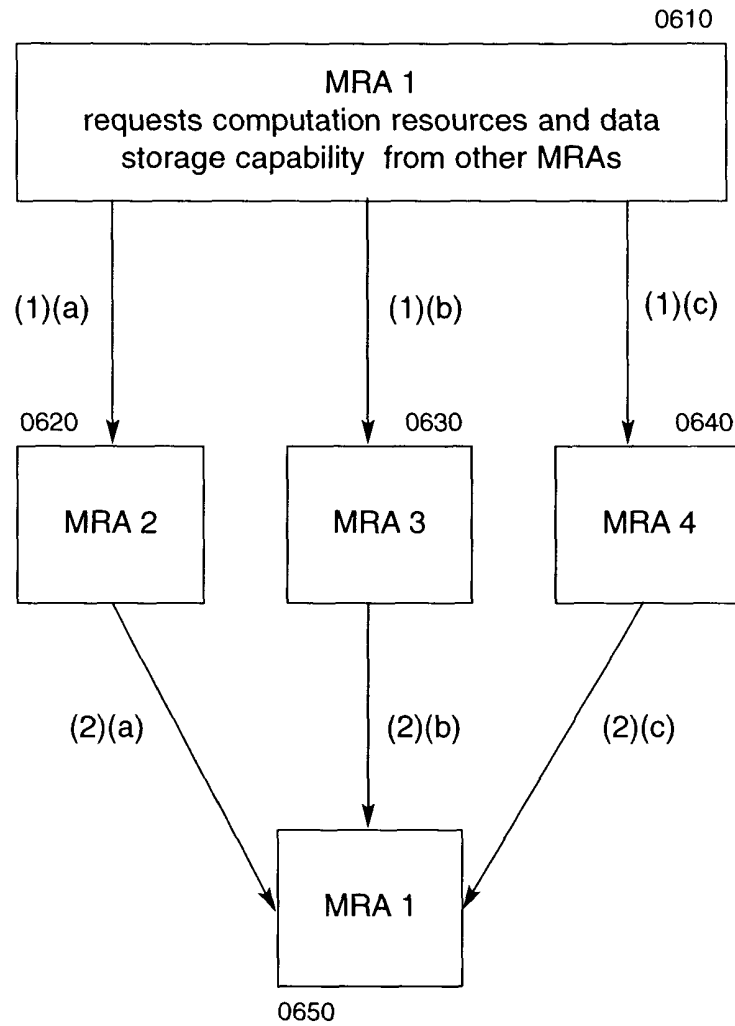


Fig 7: Sharing Computation Resources Among MRA Nodes in Wireless Mobile MRS: Efficient Routing of Database and Analytical Functions

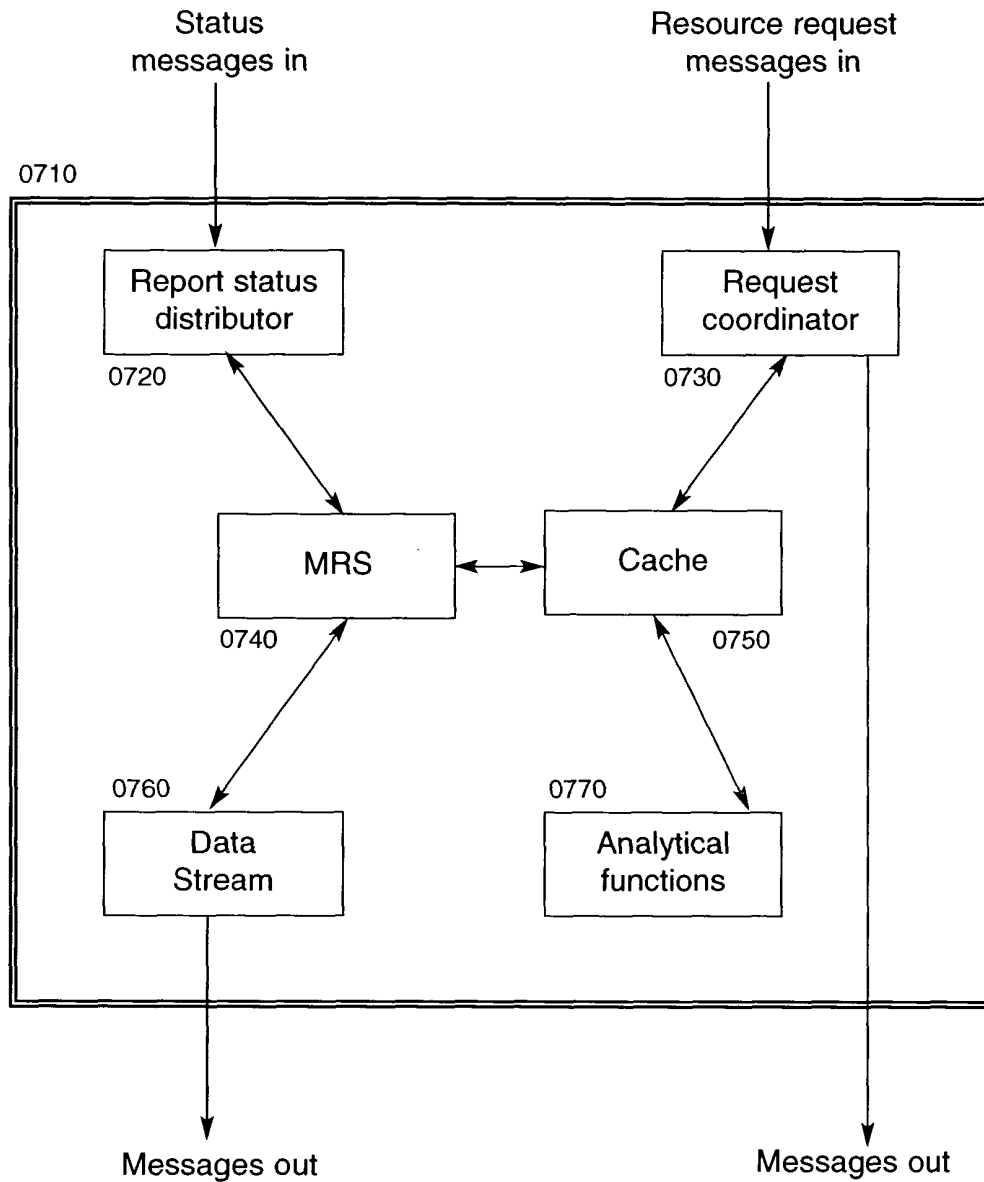
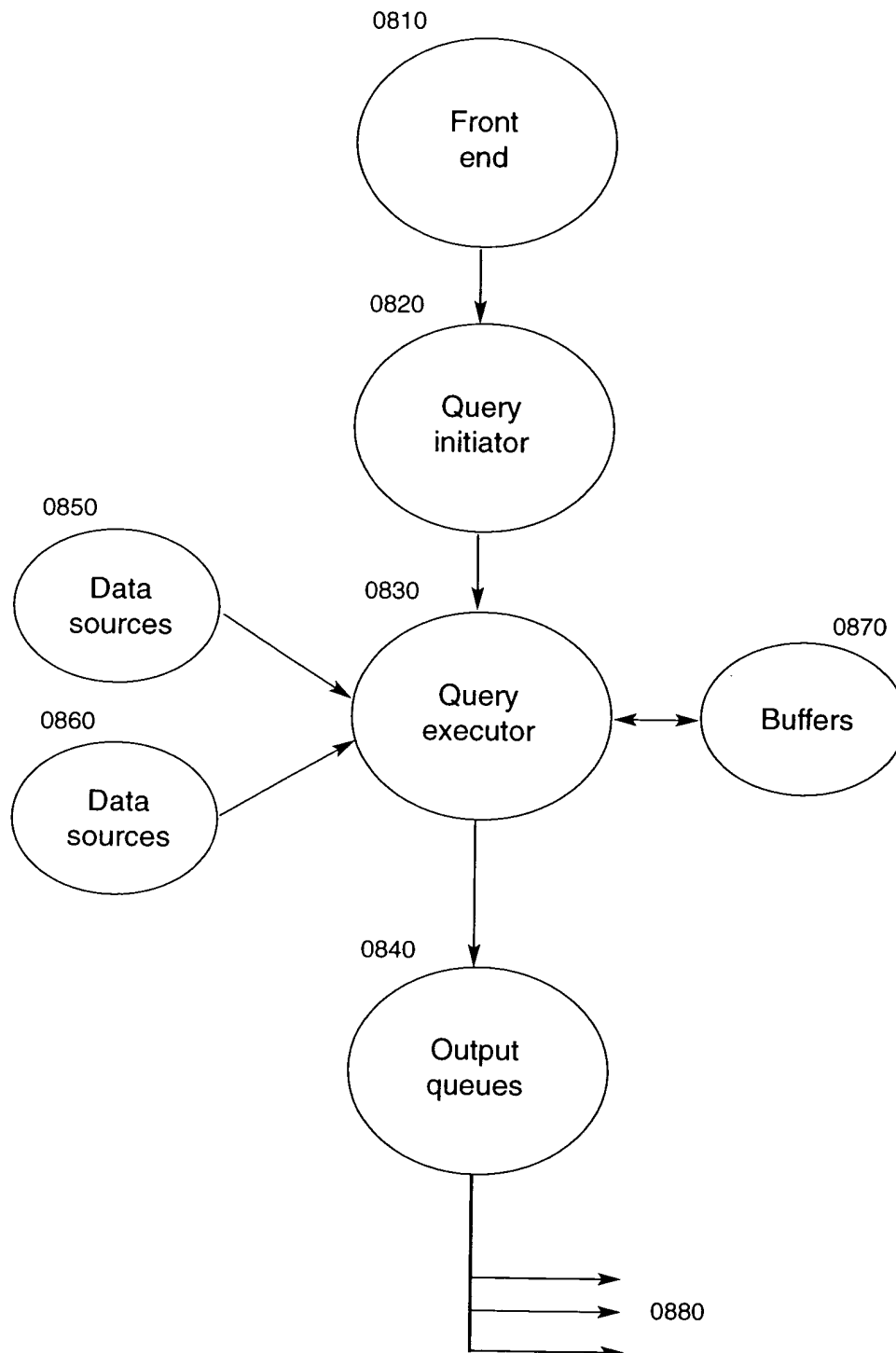


Fig 8: Database Coordination in Distributed MRS



**Fig 9: Dynamic Distributed Object Relational Database
Data Flow Process**

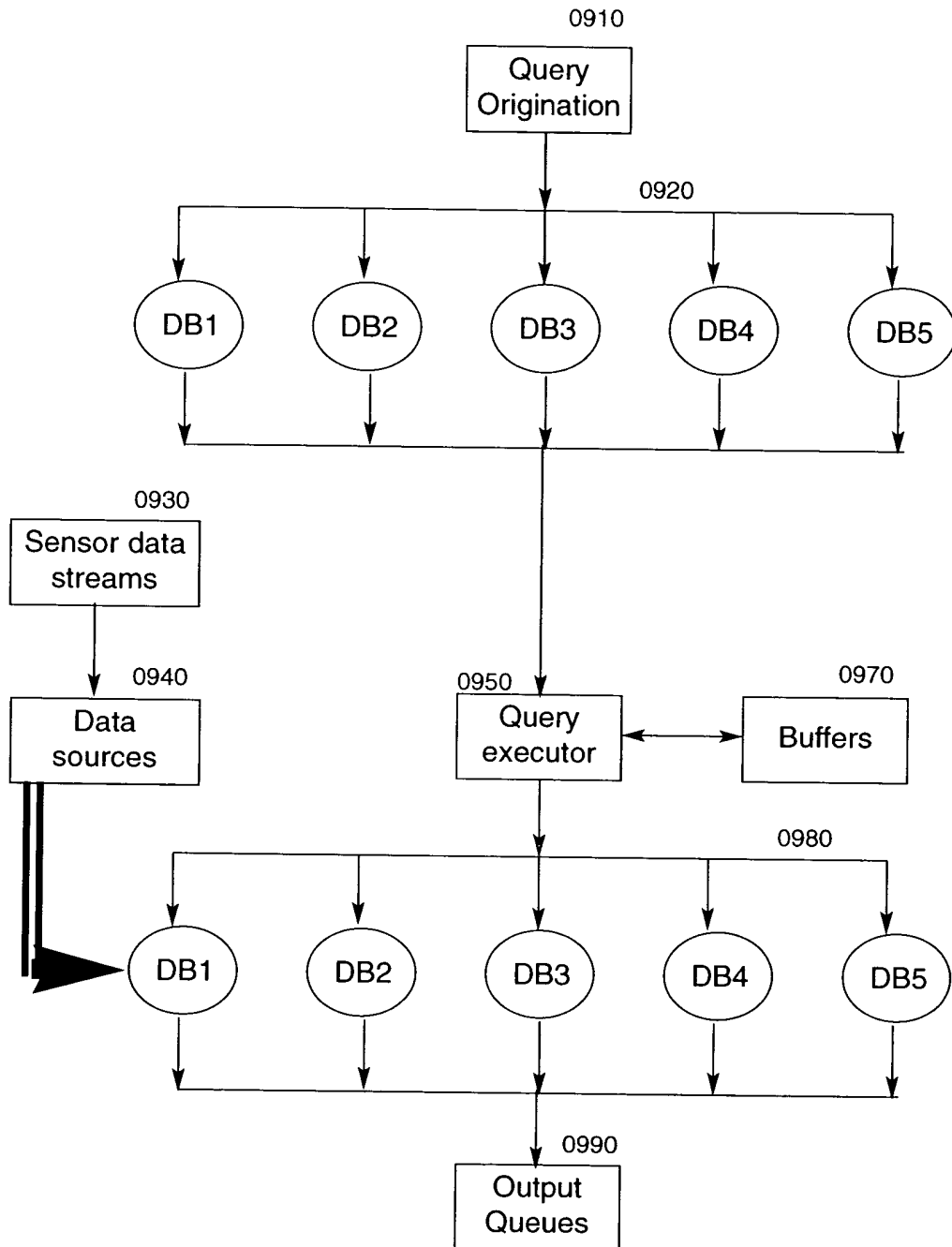


Fig 10: Temporal Objects in ORDbMS

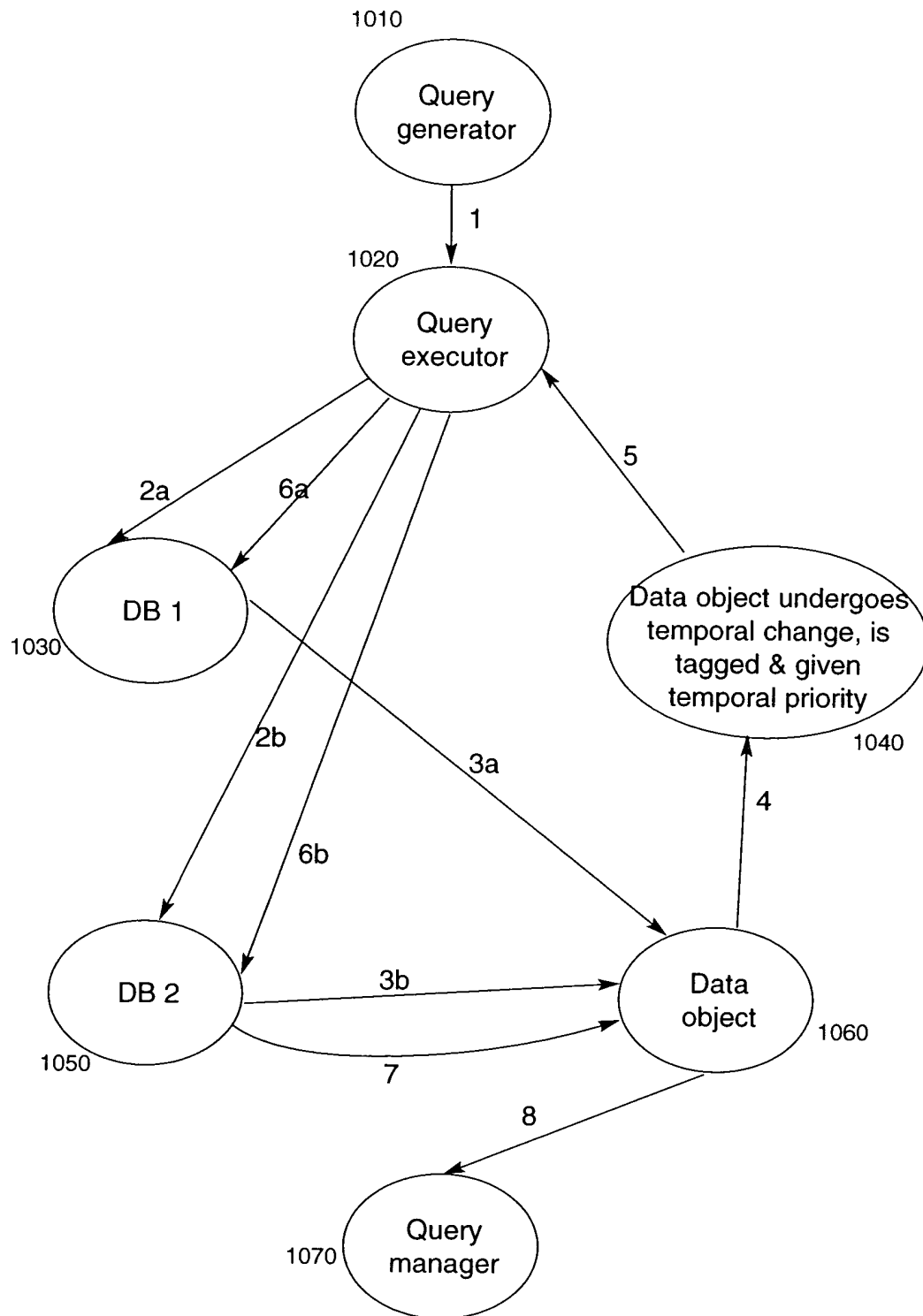


Fig 11: Mobile Grid Dynamics

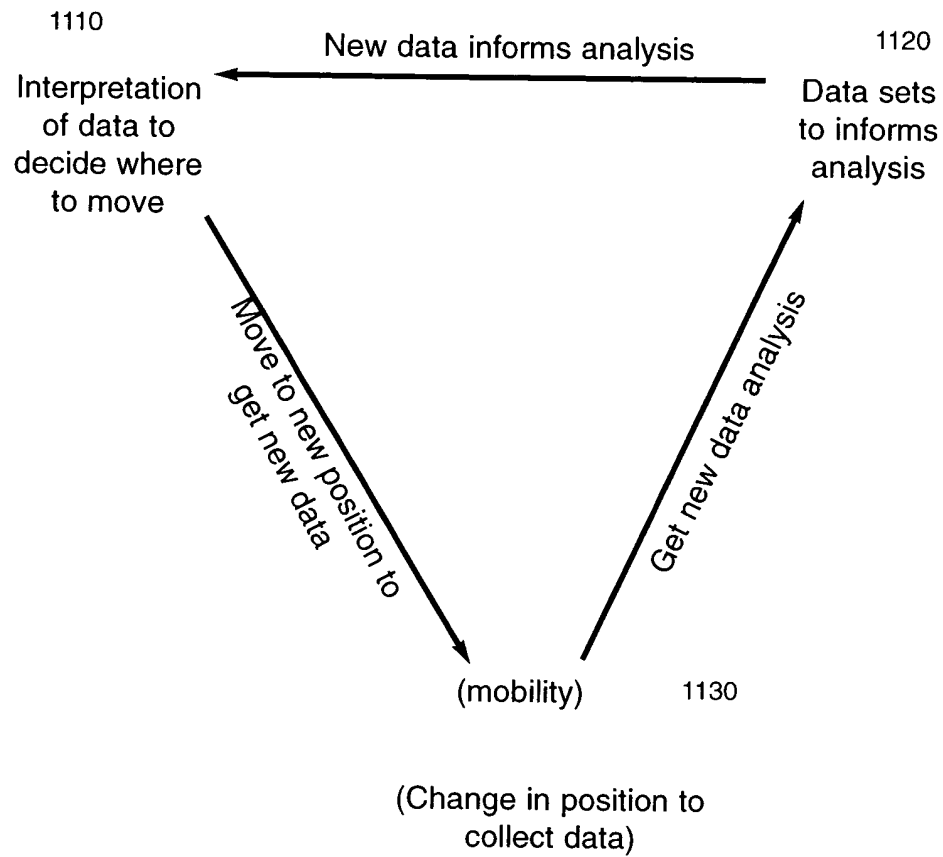
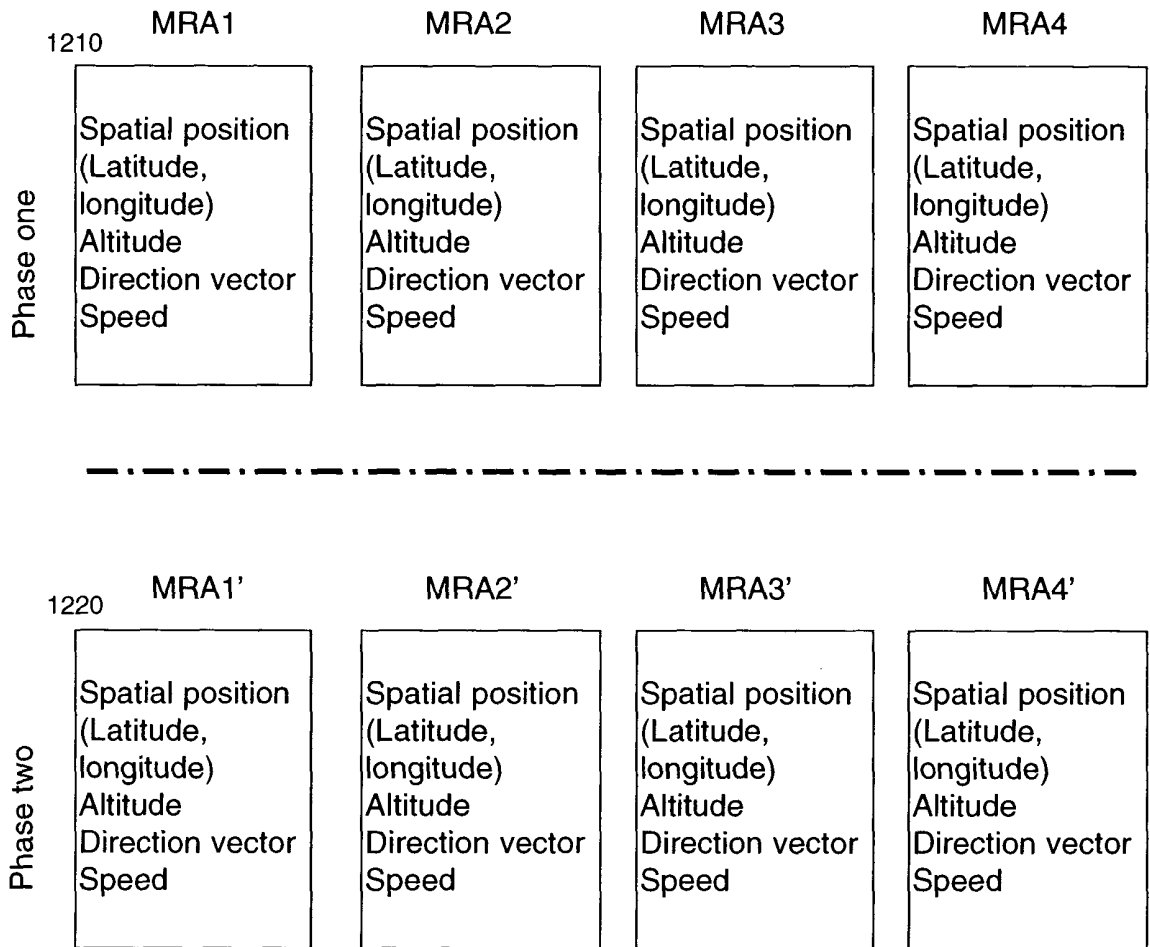


Fig 12: Autonomous Blackboards For MRAs



Data set changes from phase one to phase two

Fig 13: IMSA Operations Control of MRAs

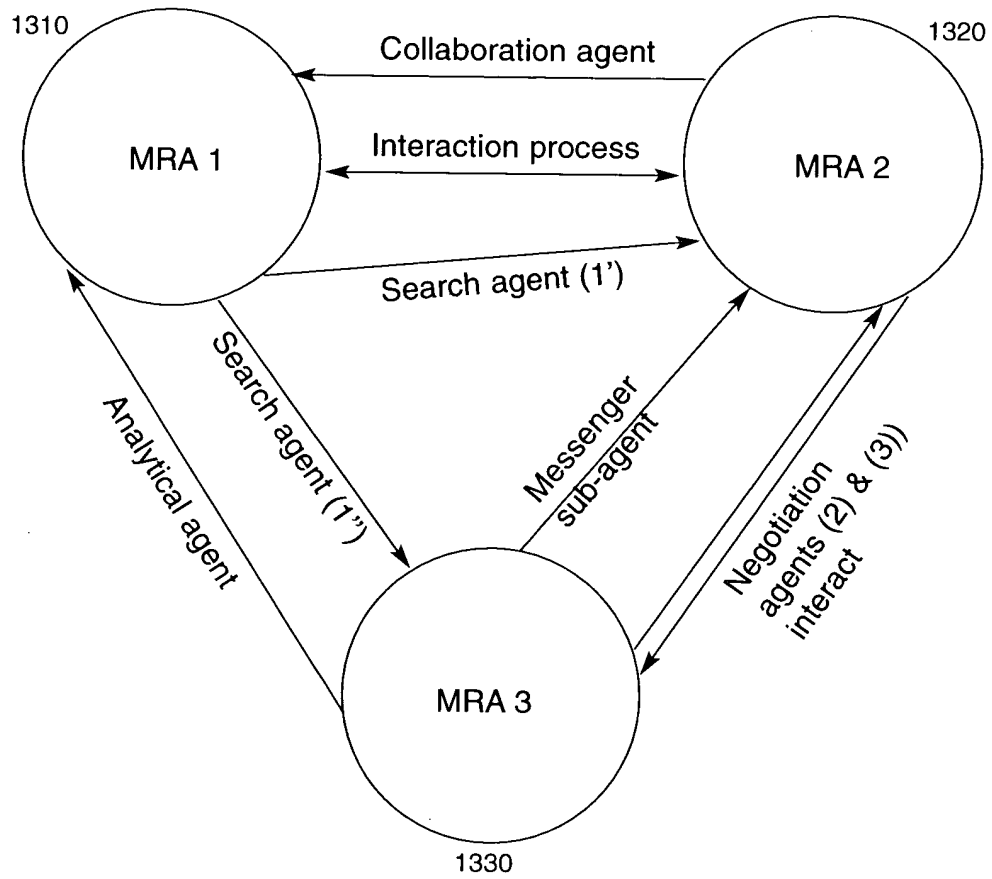


Fig 14: MRA Juvenile and Adult Training Levels

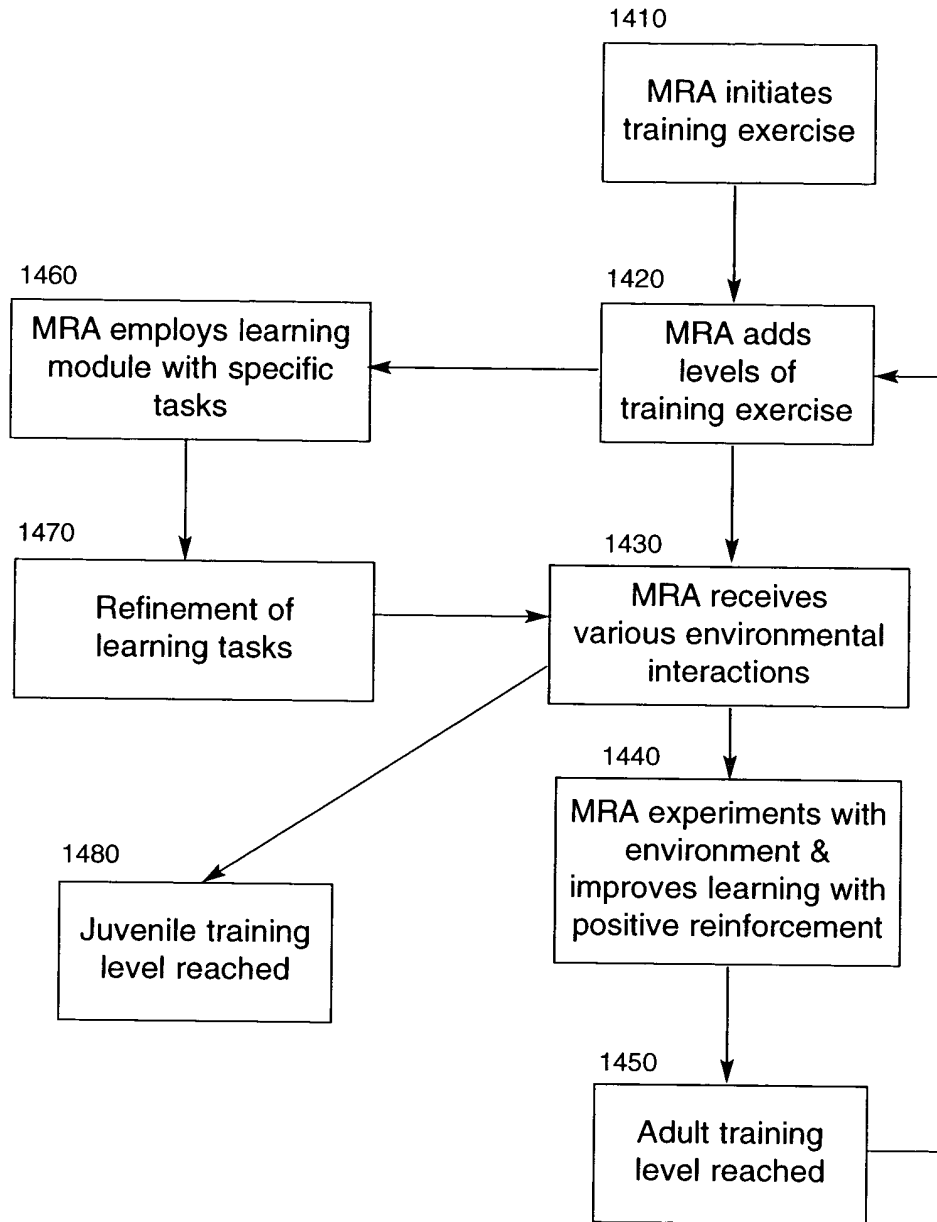


Fig 15: MRA Attitude Biases

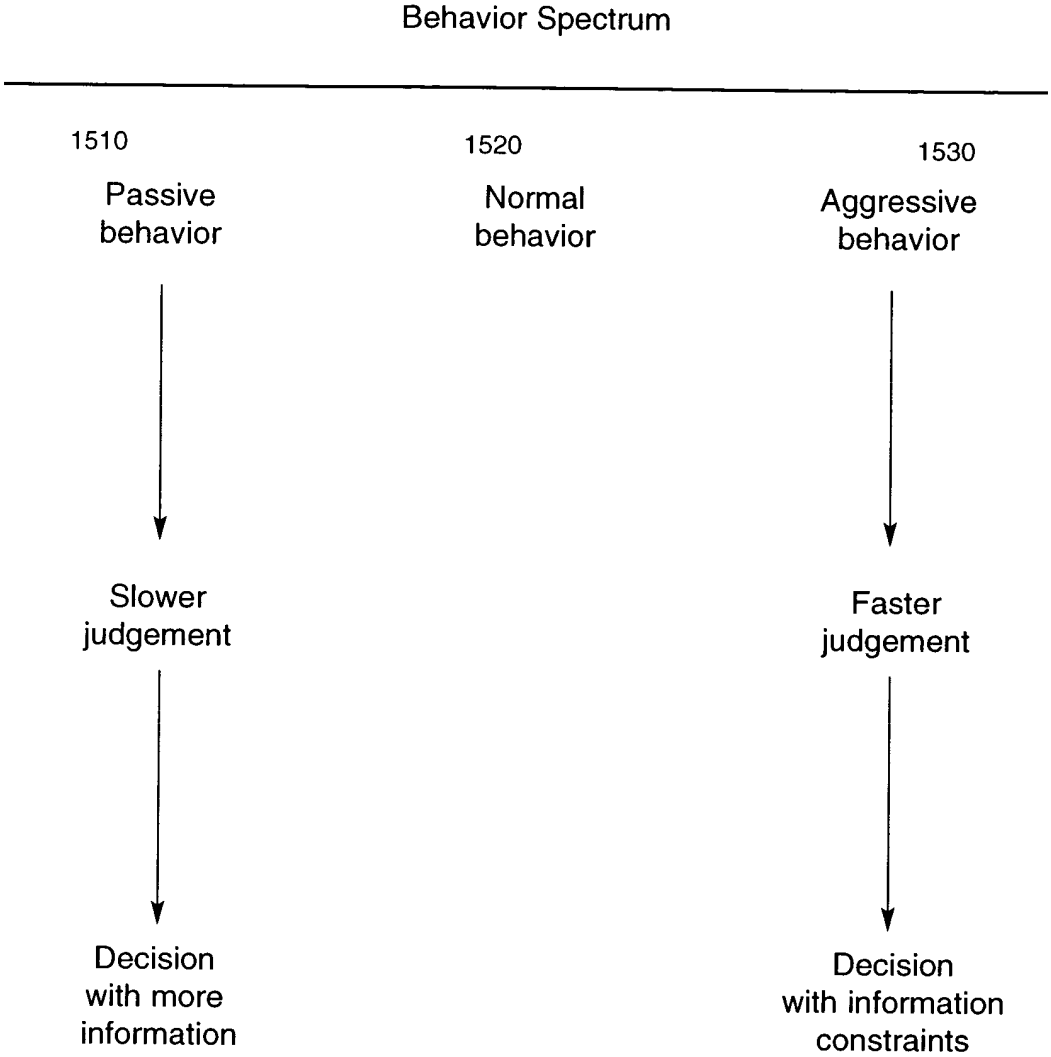


Fig 16: Learning From Environmental Interaction: Adaptation

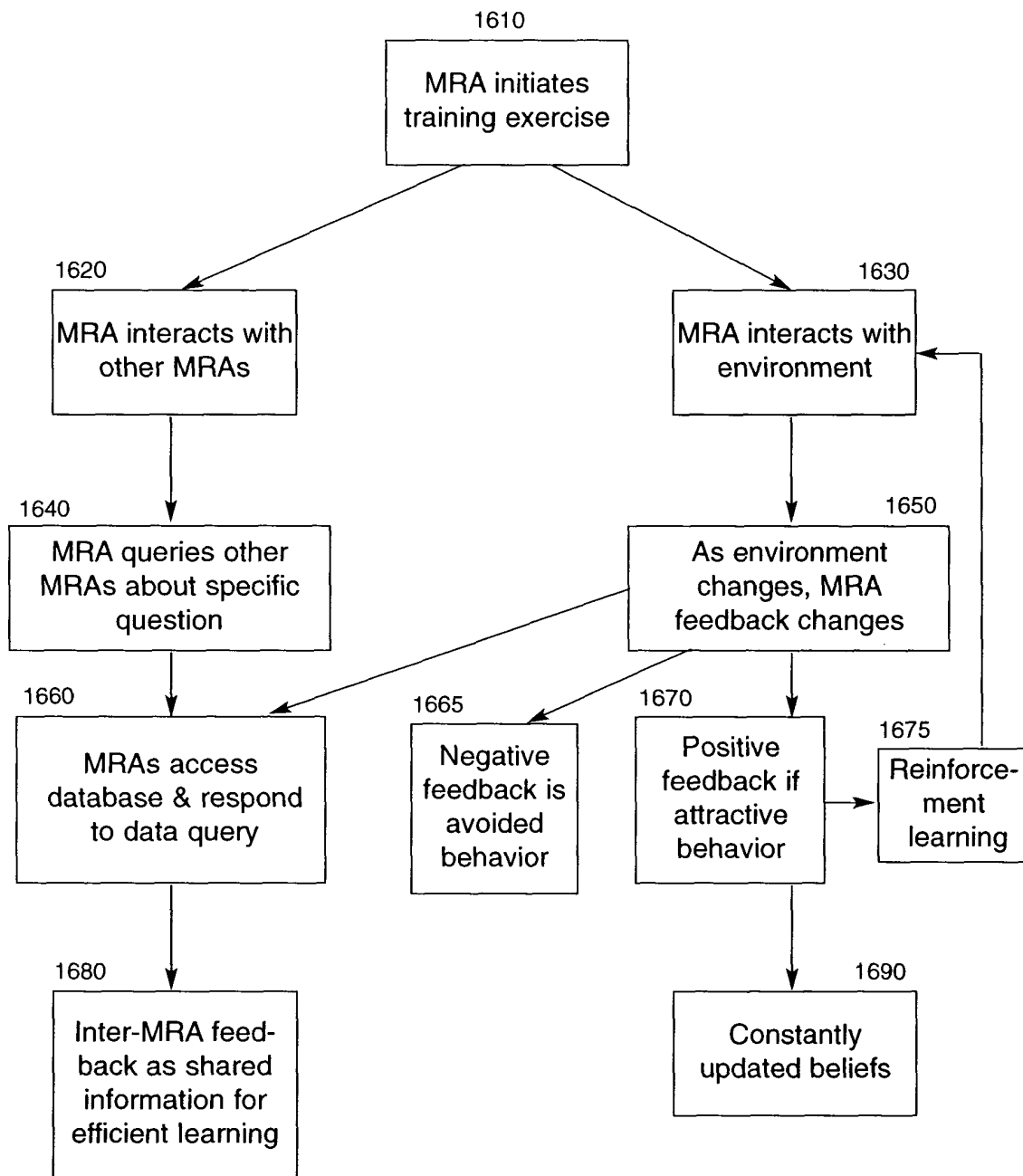


Fig 17: MRA Training Process - “Experience” of Environmental Interaction Combined With Group Sensor Data

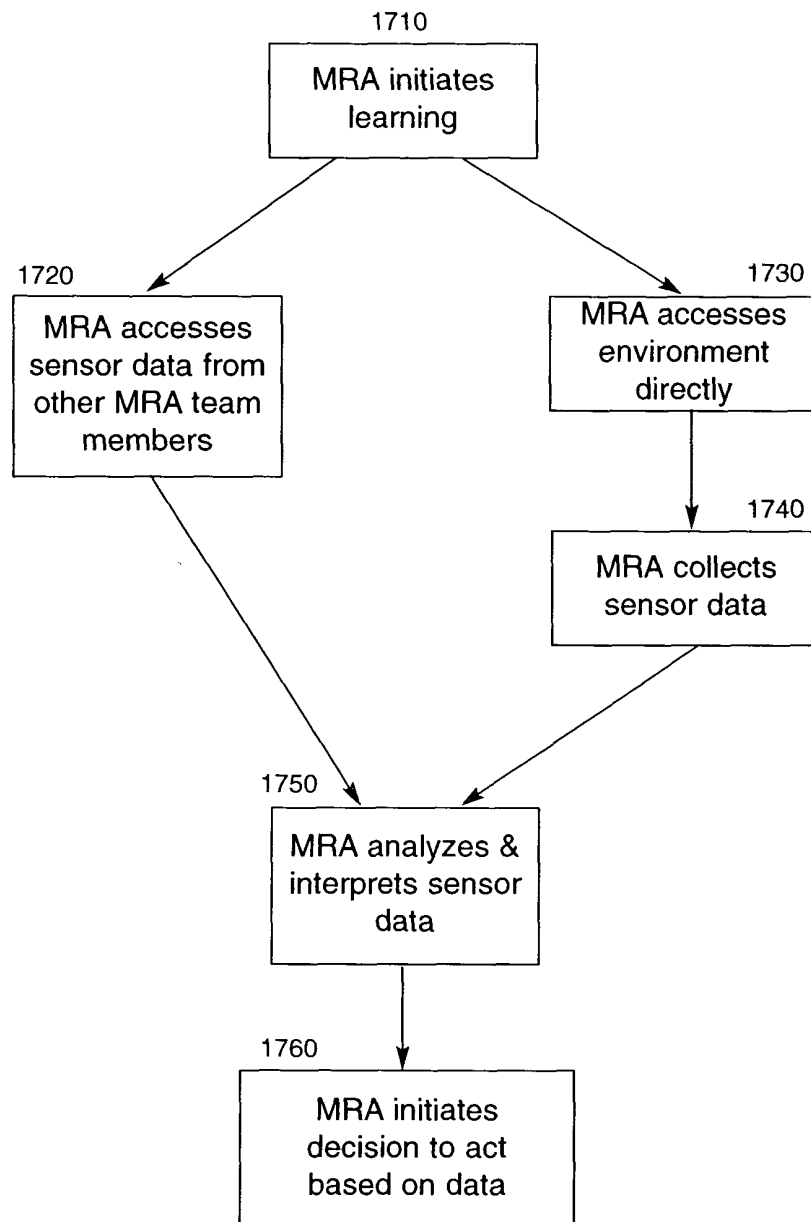


Fig 18: Reinforcement Learning:
(A) Intensity of Sensor Data and (B) Quantity of Sensor Data

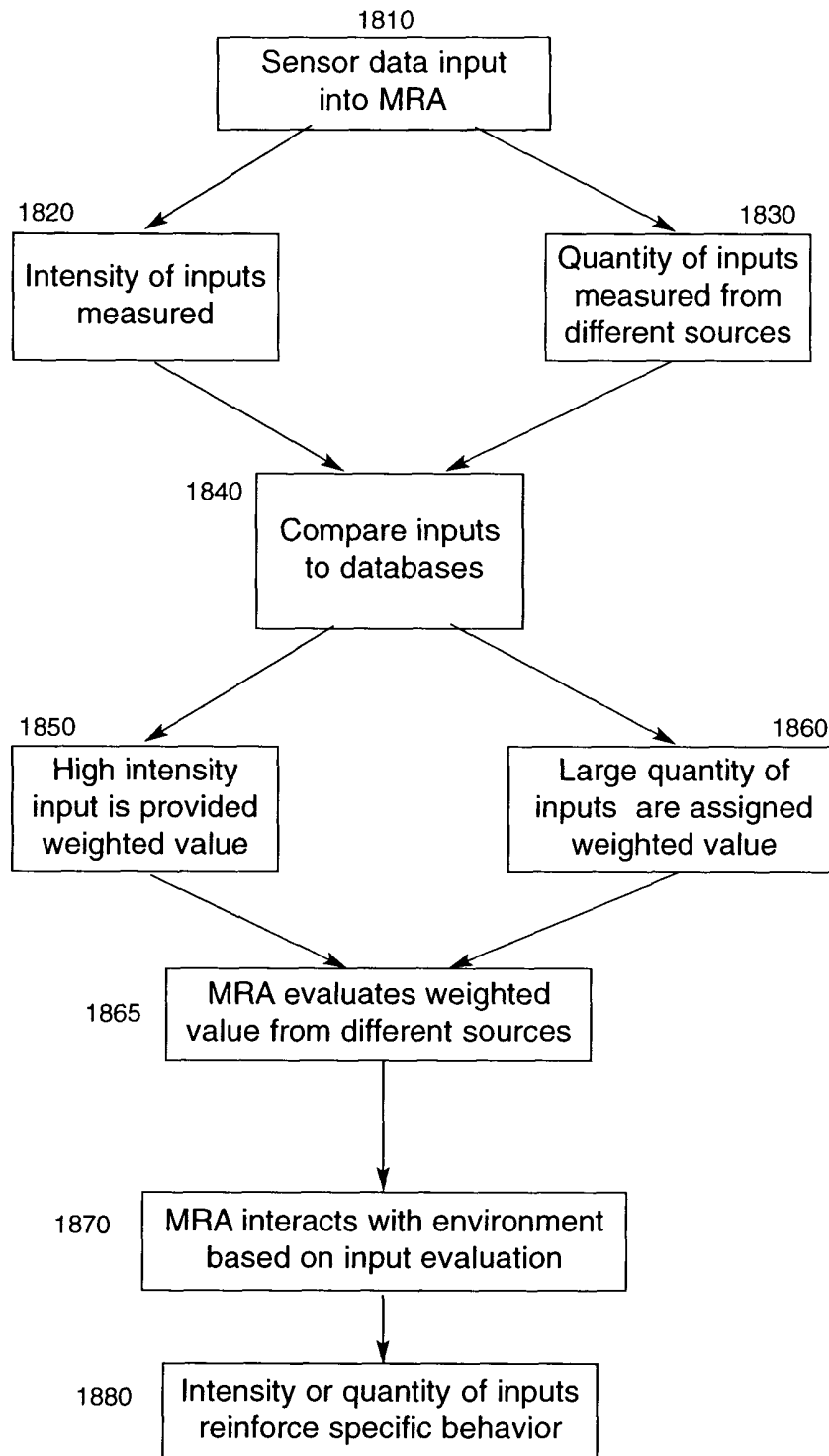


Fig 19: Hybrid Learning Model With Time Constraints

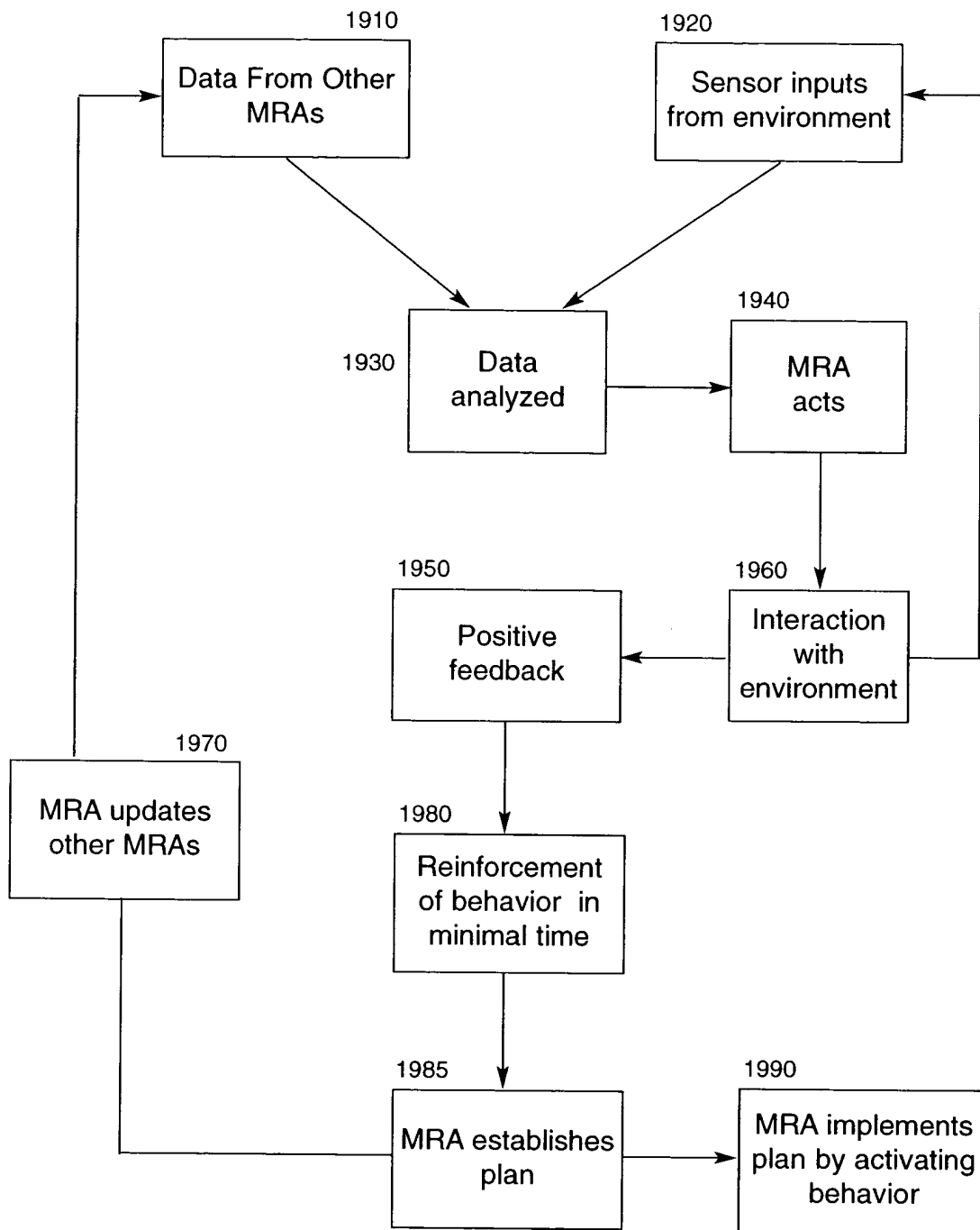


Fig 20: Social Learning: Learning From Inter-MRA Interaction

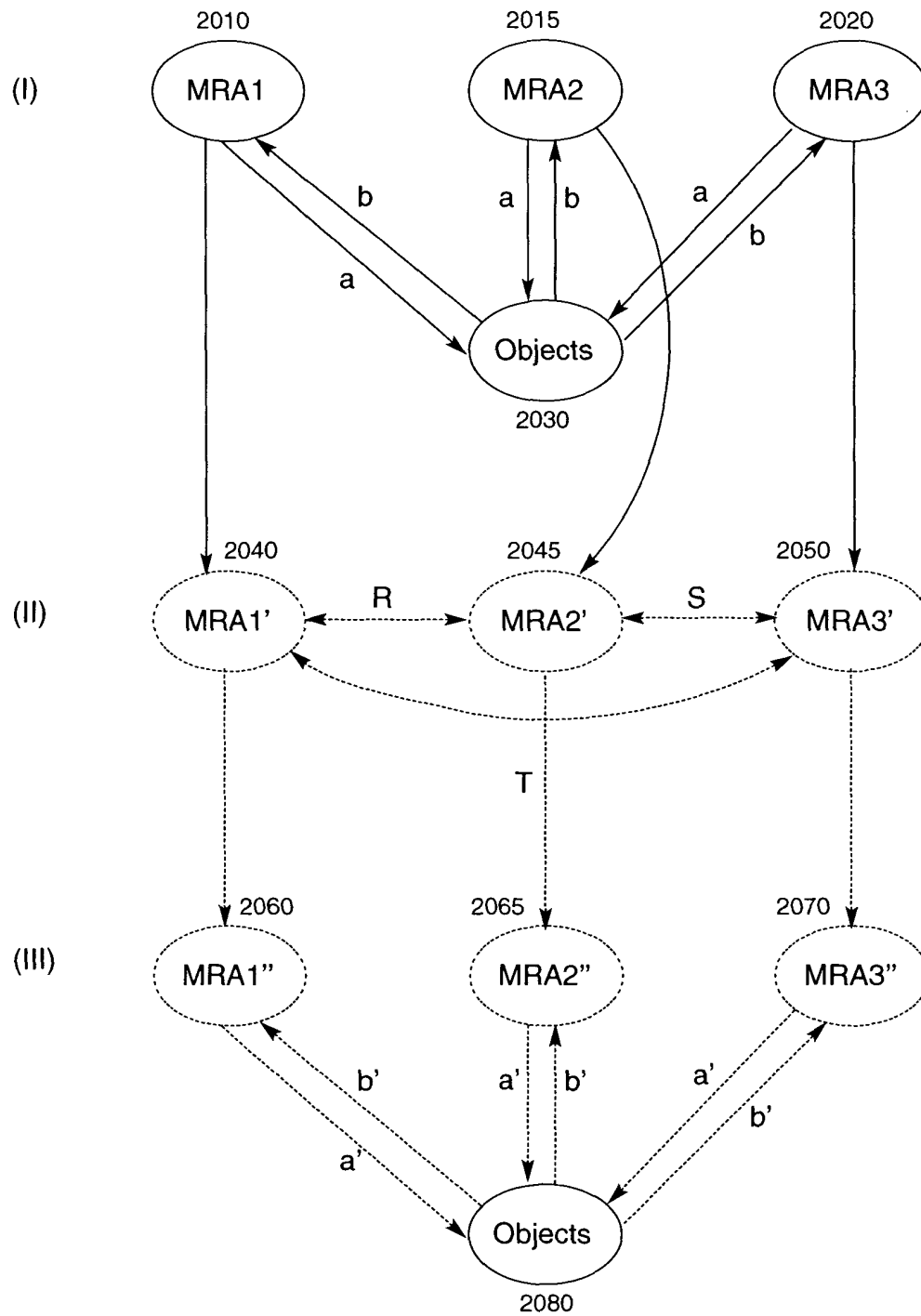


Fig 21: MRAs That Teach Other MRAs

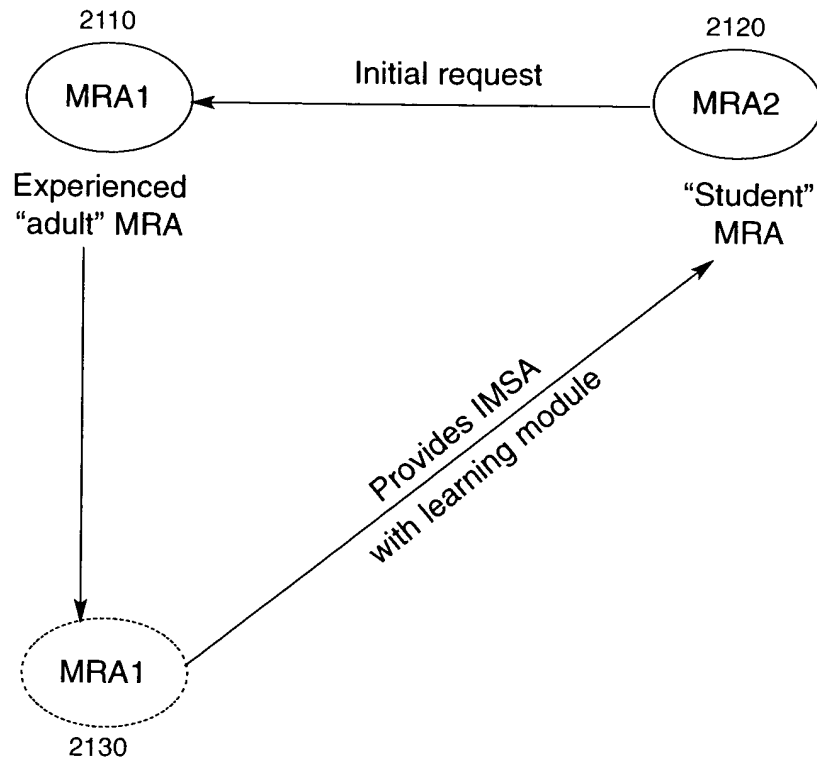
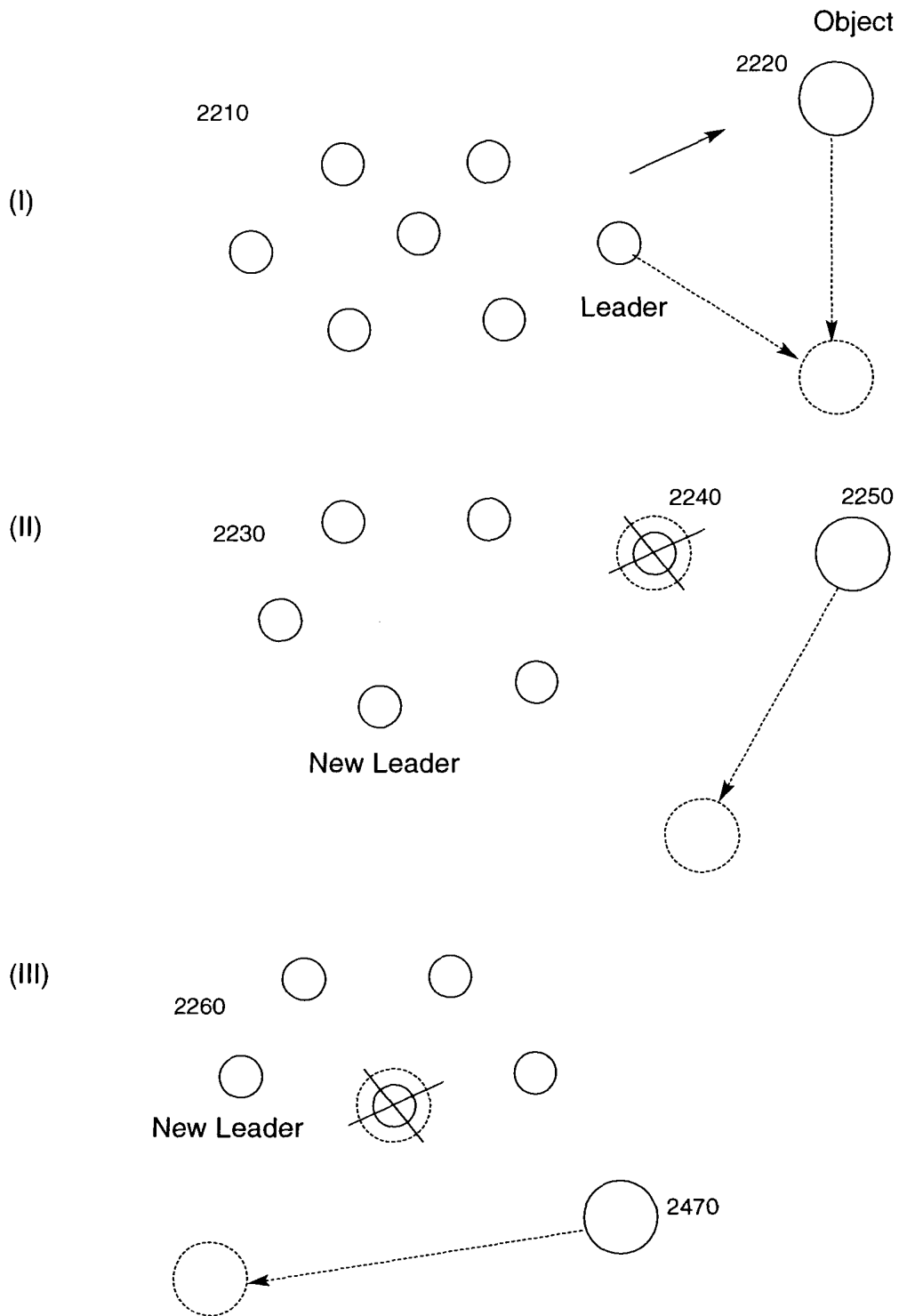


Fig 22: Asymmetric MRA Leadership and the Emergence of Temporary Hubs



**Fig 23: Specialized Learning (in Teams):
Division of Labor in Self-Organizing Groups**

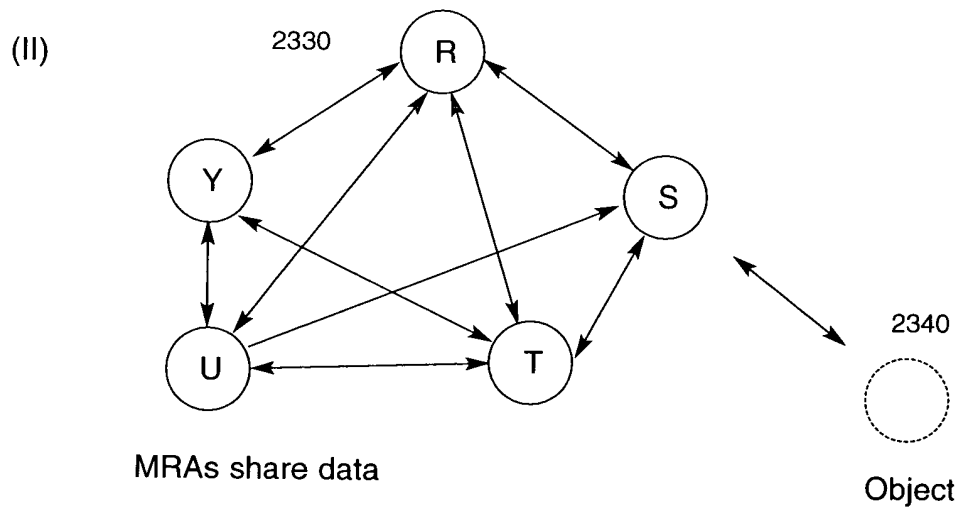
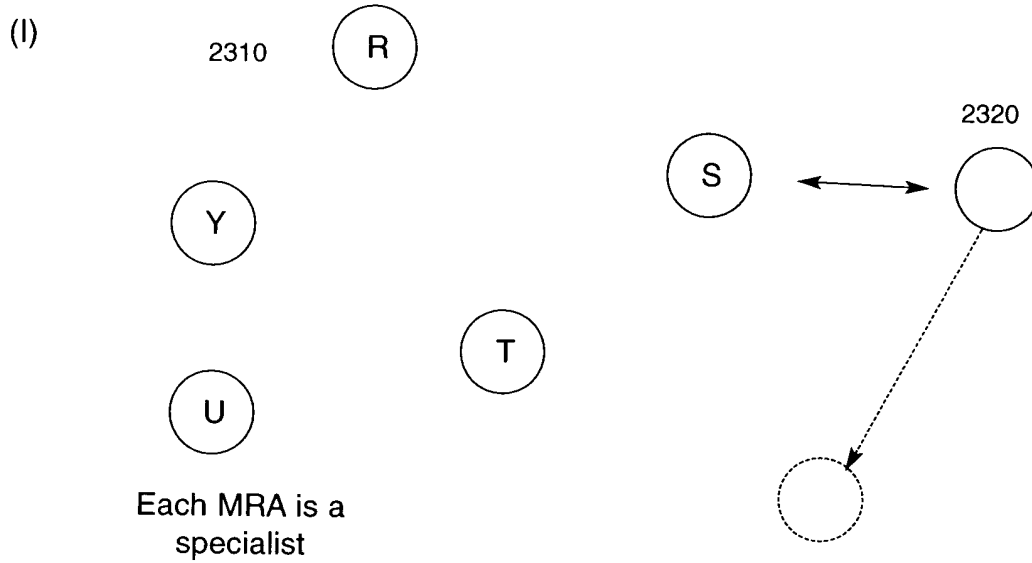


Fig 24: Auto Specialization: Self Organization by Task Division for Individual Specialization

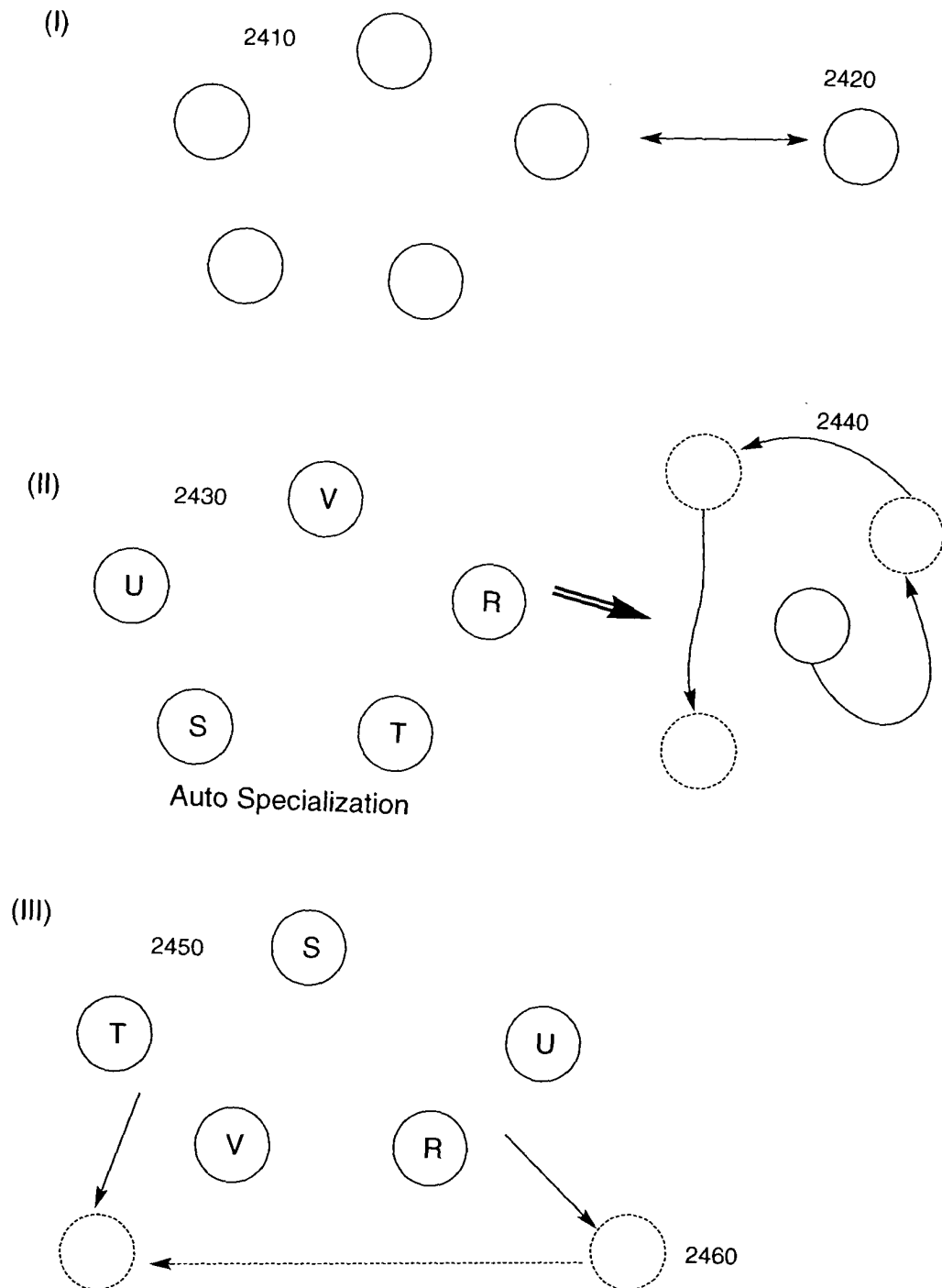


Fig 25: Self Organizing Map

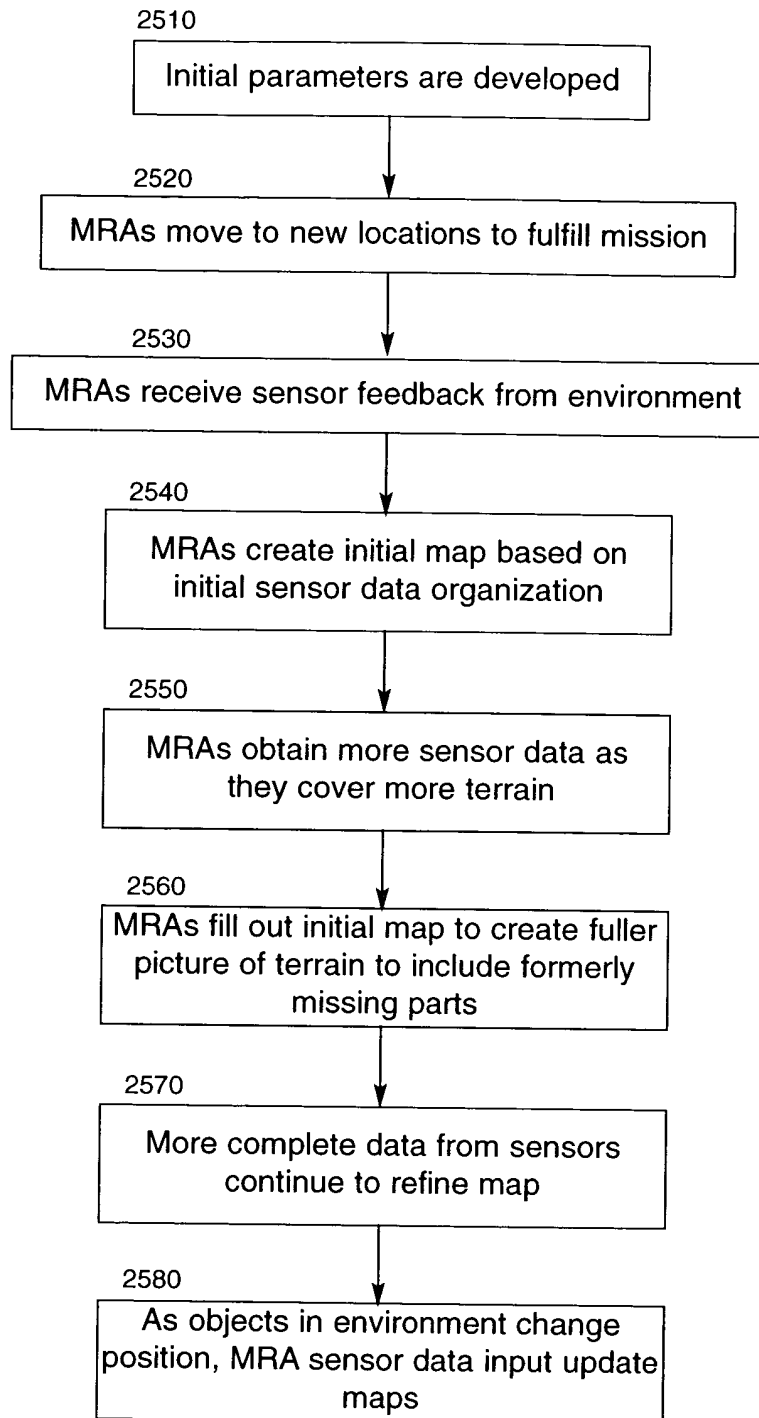


Fig 26: Flow Chart of Genetic Algorithm

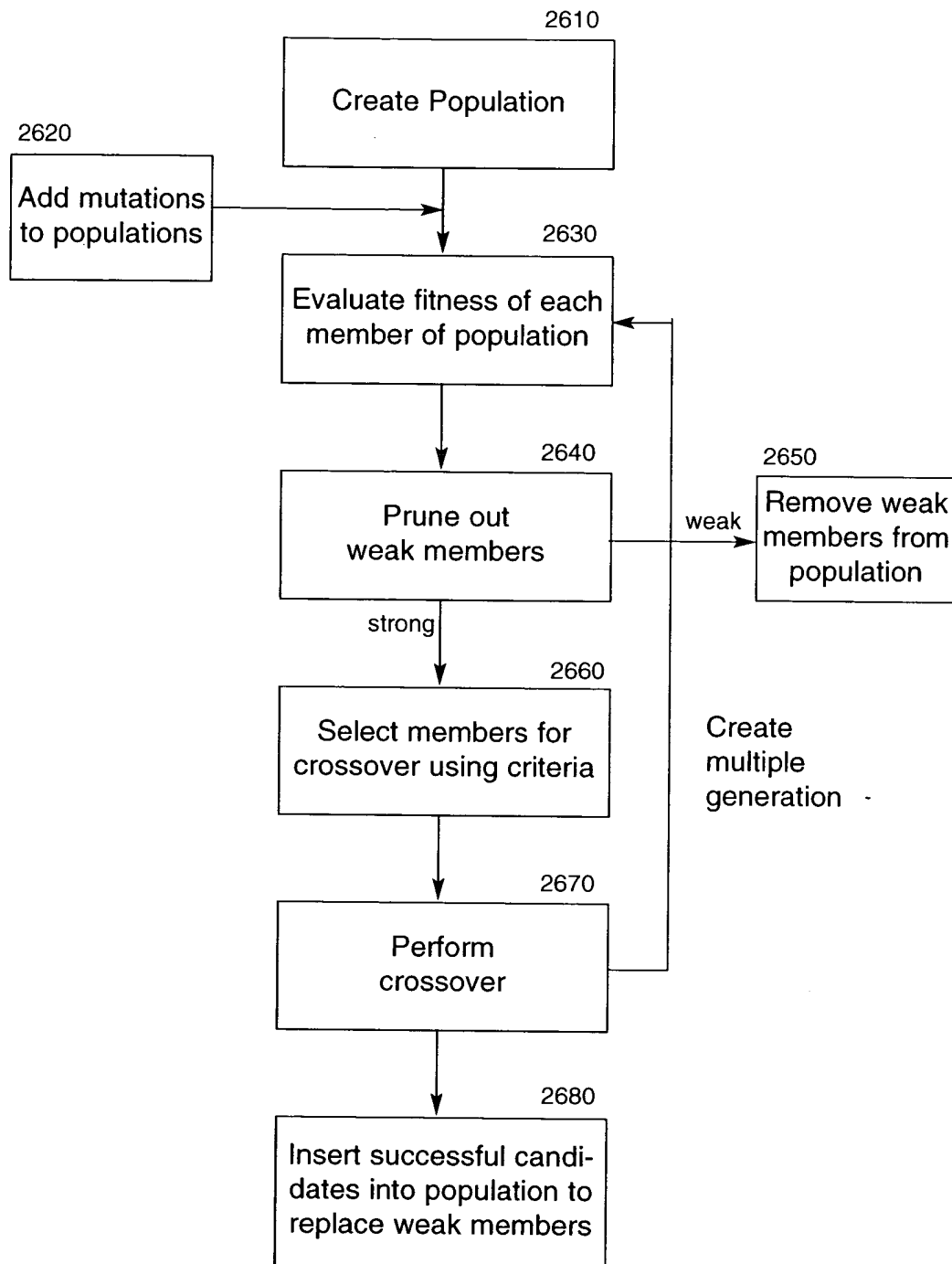


Fig 27: Binary Genetic Algorithm Model

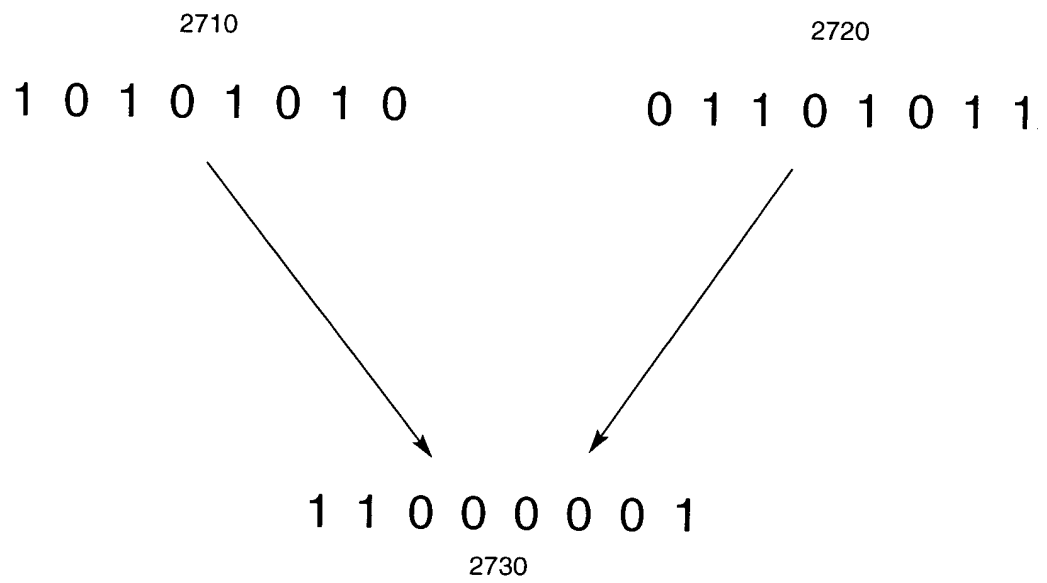


Fig 28: Tree Architecture - Genetic Programming Model

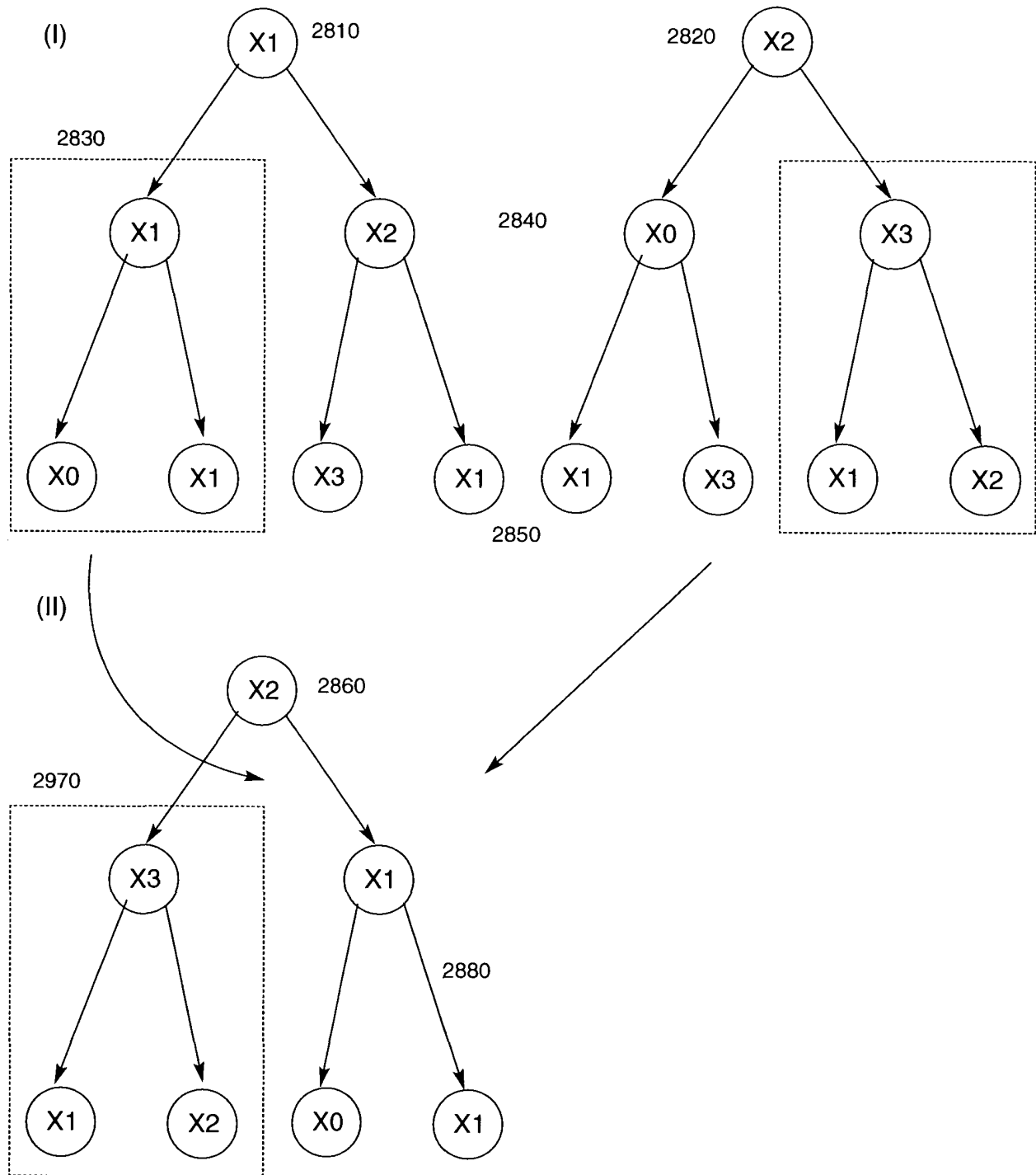


Fig 29: Parallel Subpopulations Fitness Evaluation

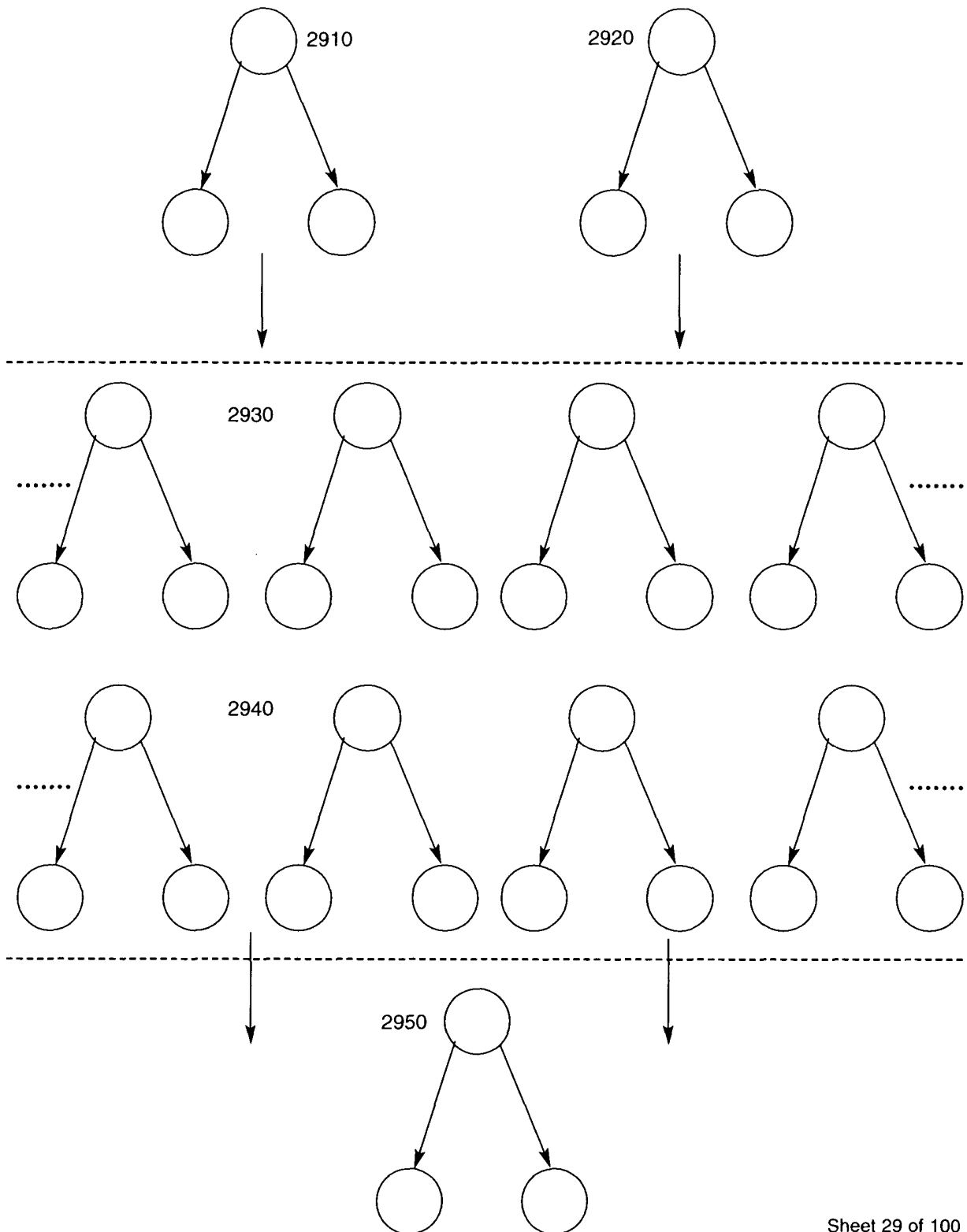


Fig 30: Two Layer Neural Network

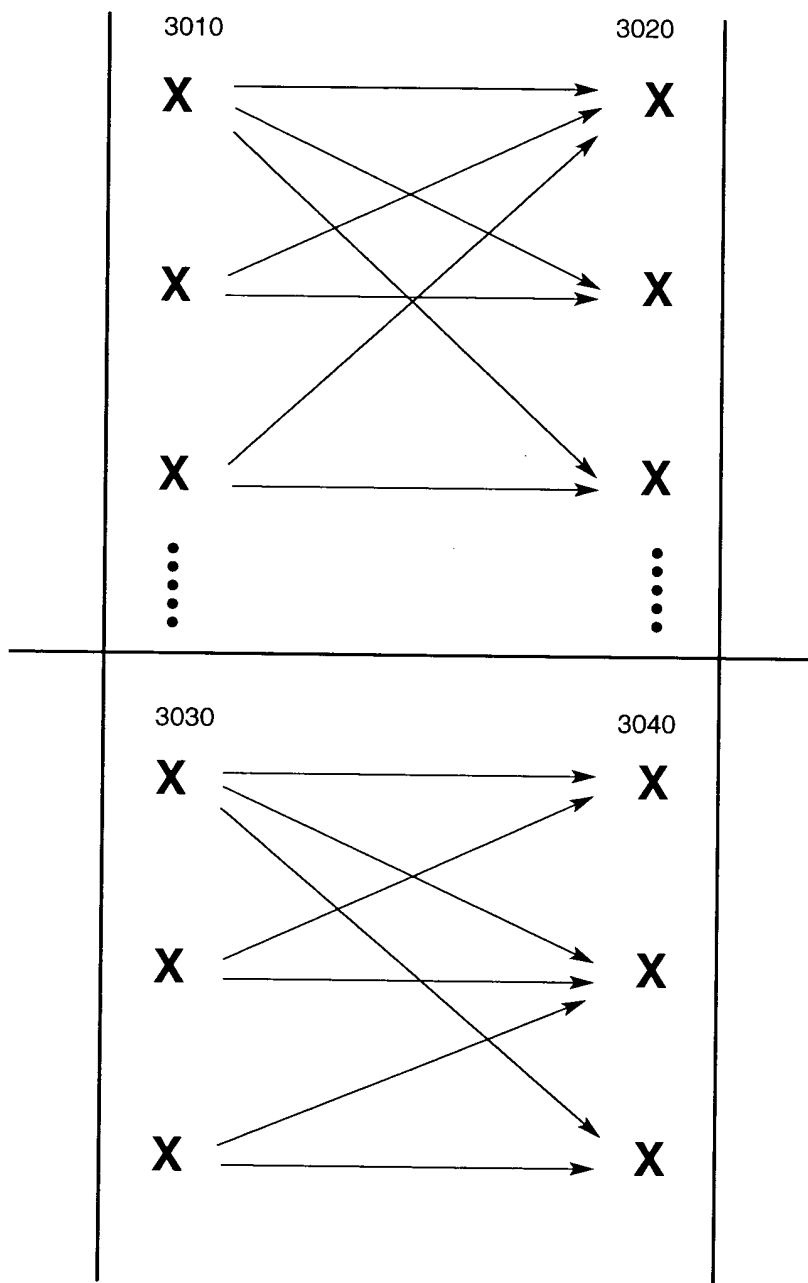


Fig 31: Artificial Neural Network Connection Weights

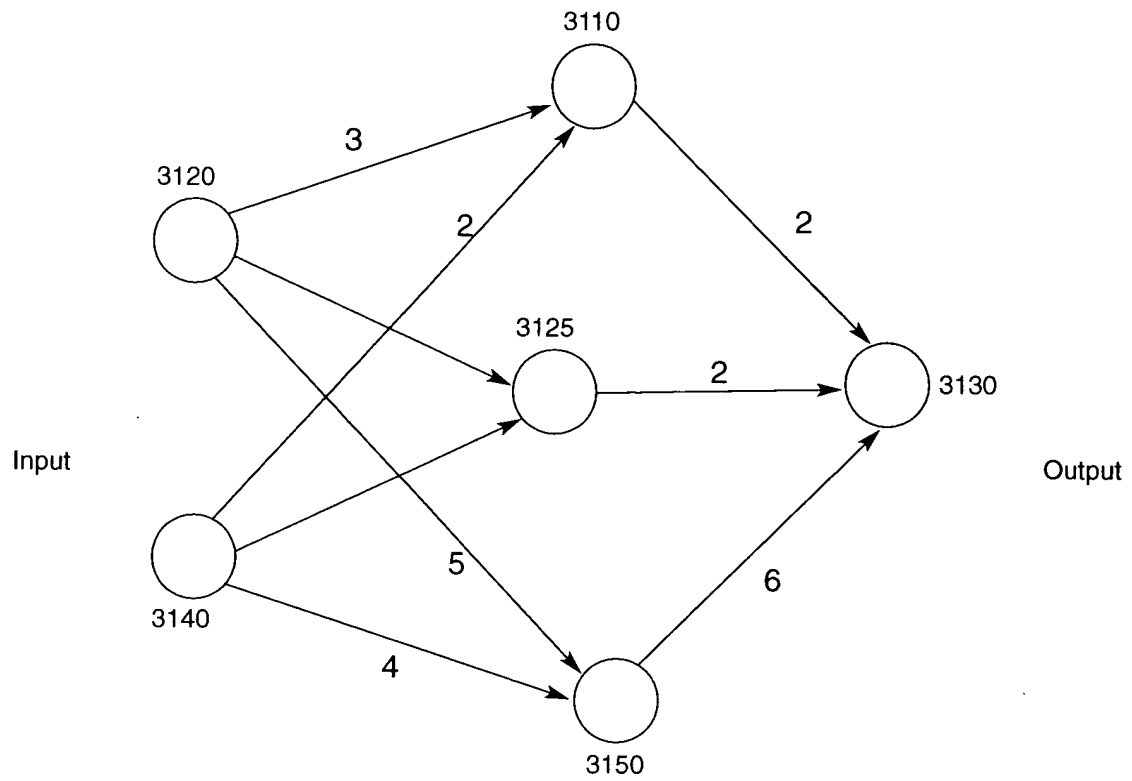


Fig 32: Genetic Programming Calculates Initial Weights

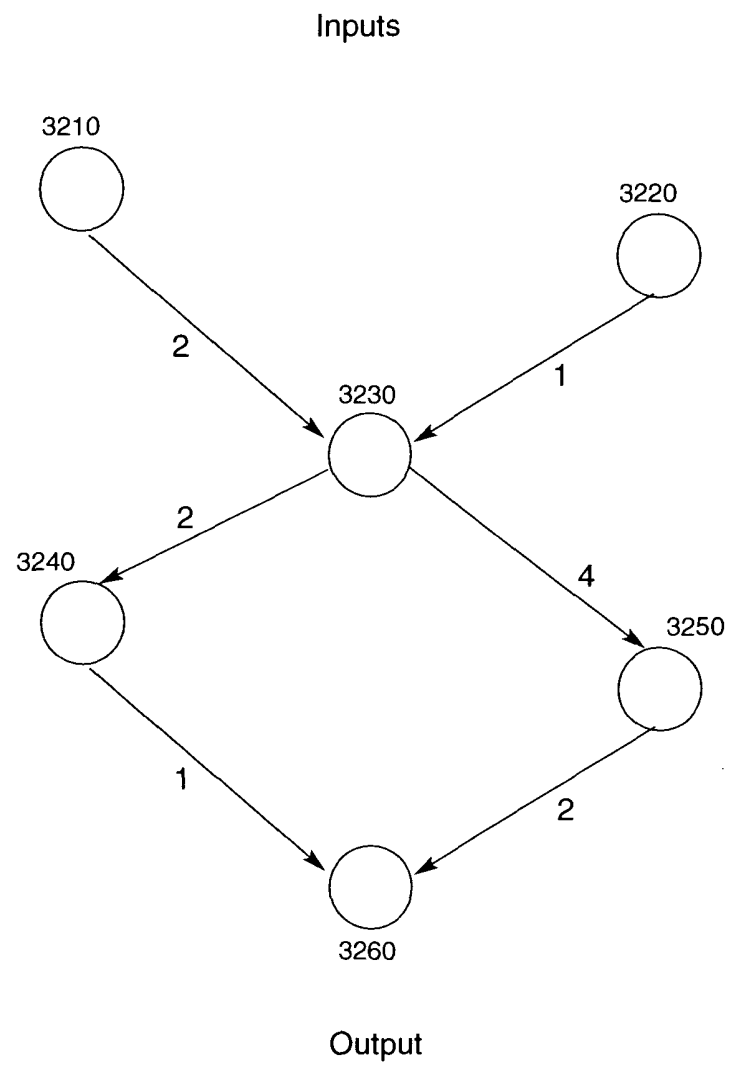


Fig 33: Genetic Programming Applied to Indeterministic ANN

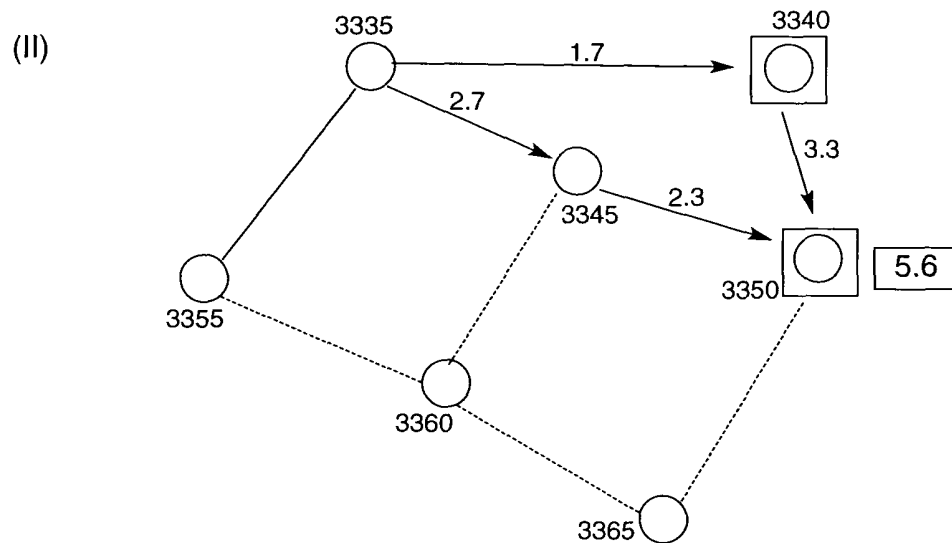
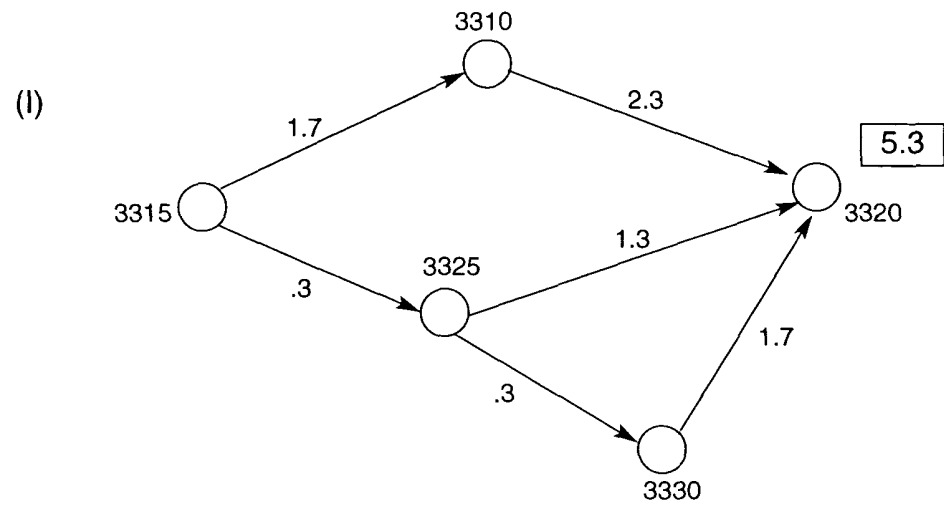


Fig 34: Neuroevolution - Evolutionary A-NN Connection and Node Additions

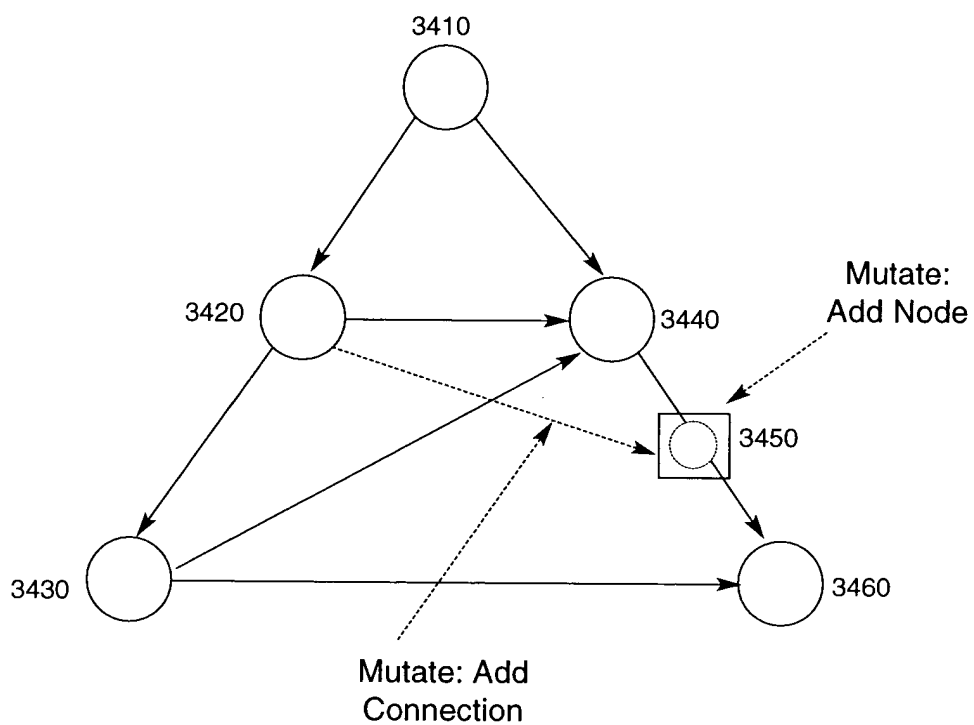
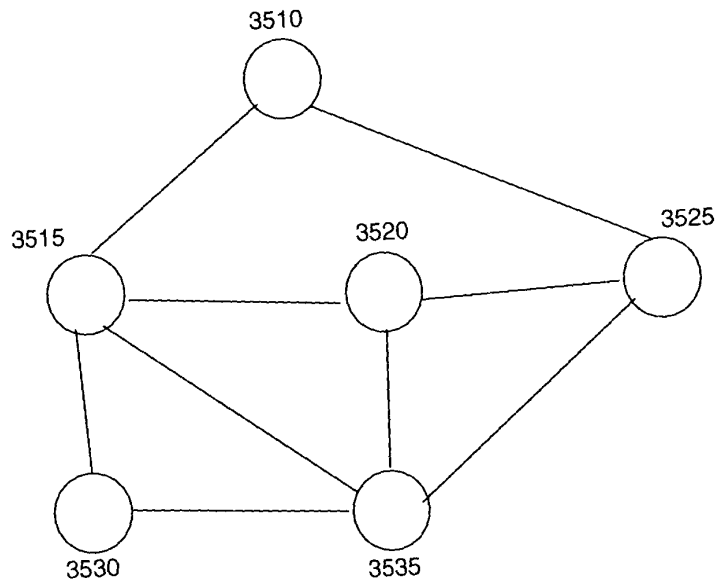


Fig 35: Evolutionary A-NN Non-deterministic Feed Forwarded

(I)



(II)

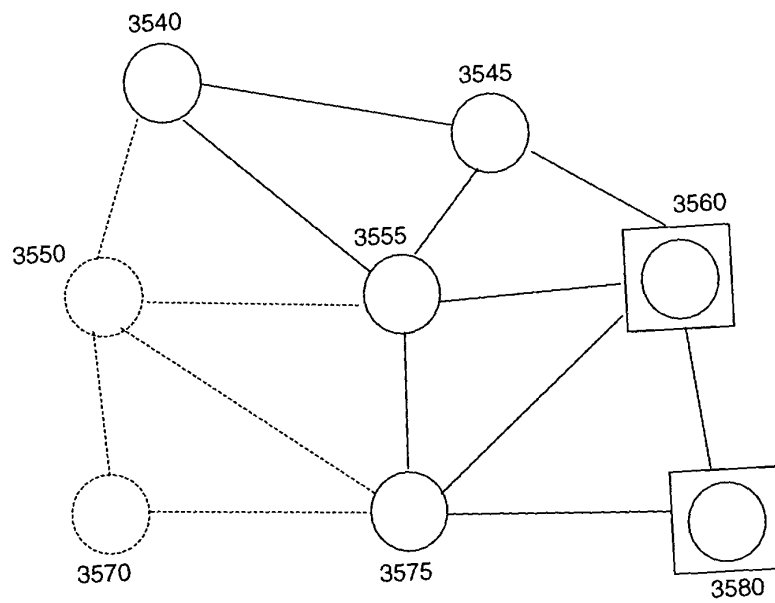
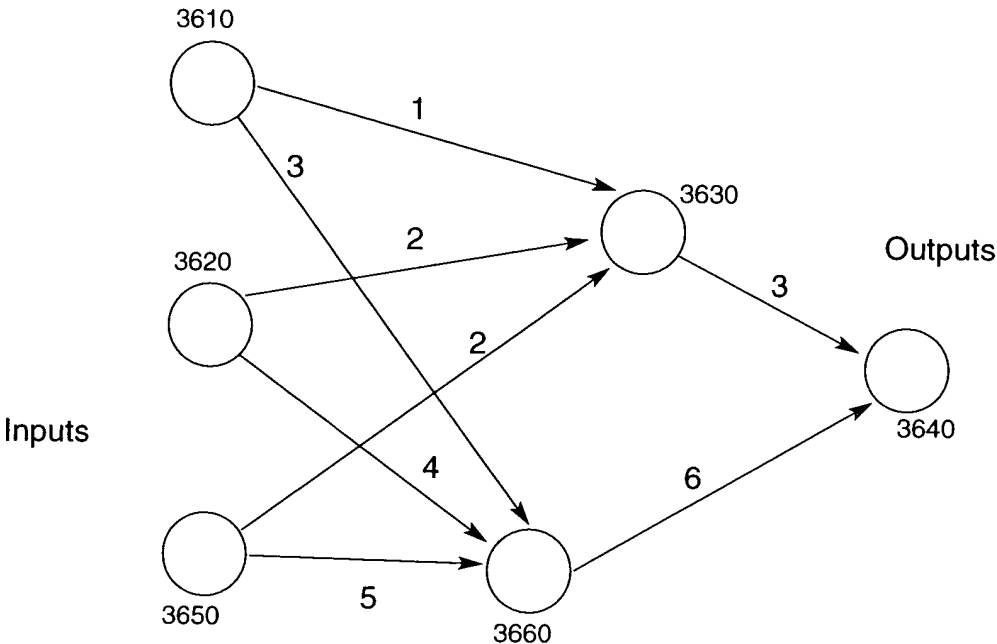
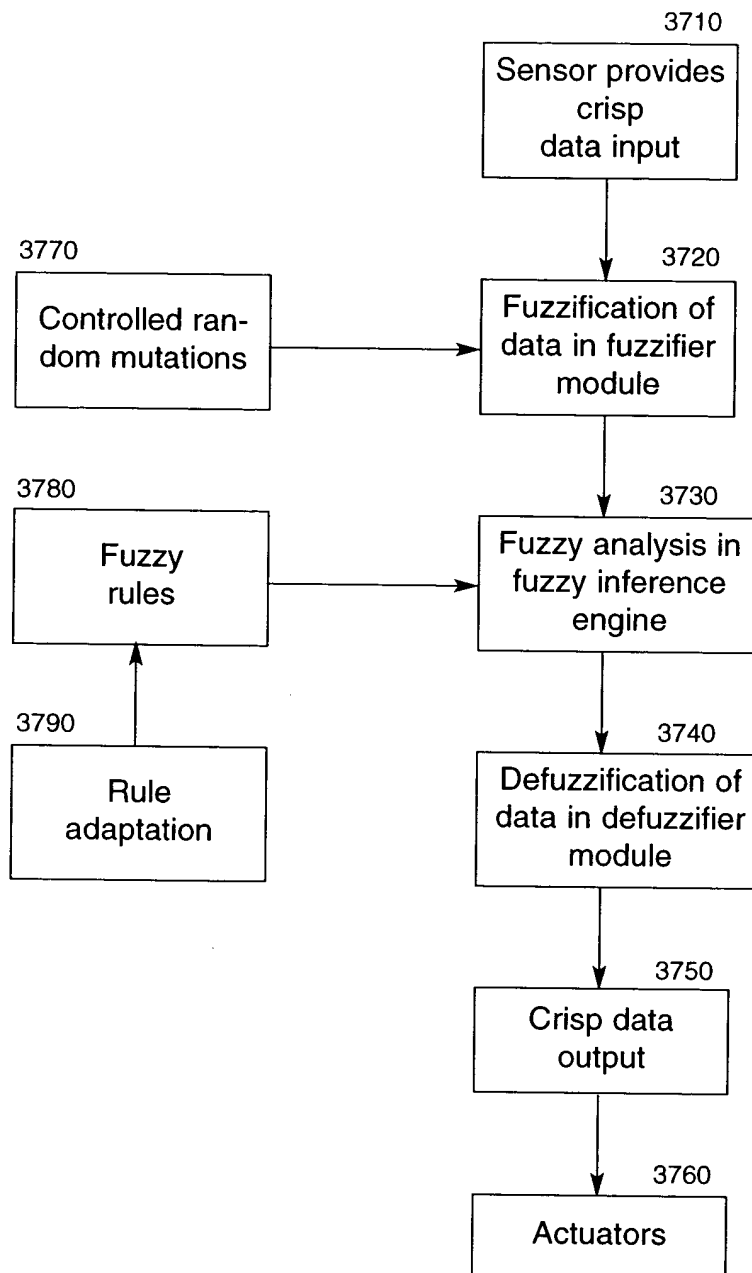


Fig 36: Evolutionary Search For Connection Weights in an ANN



3670 Genotype: 0010 0001 0110 1001 1010
Binary representation of connection weight
chromosome encoding

Fig 37: Fuzzy Logic Module



**Fig 38: Neuro Fuzzy Controller with
Two Input Variables & Three Rules**

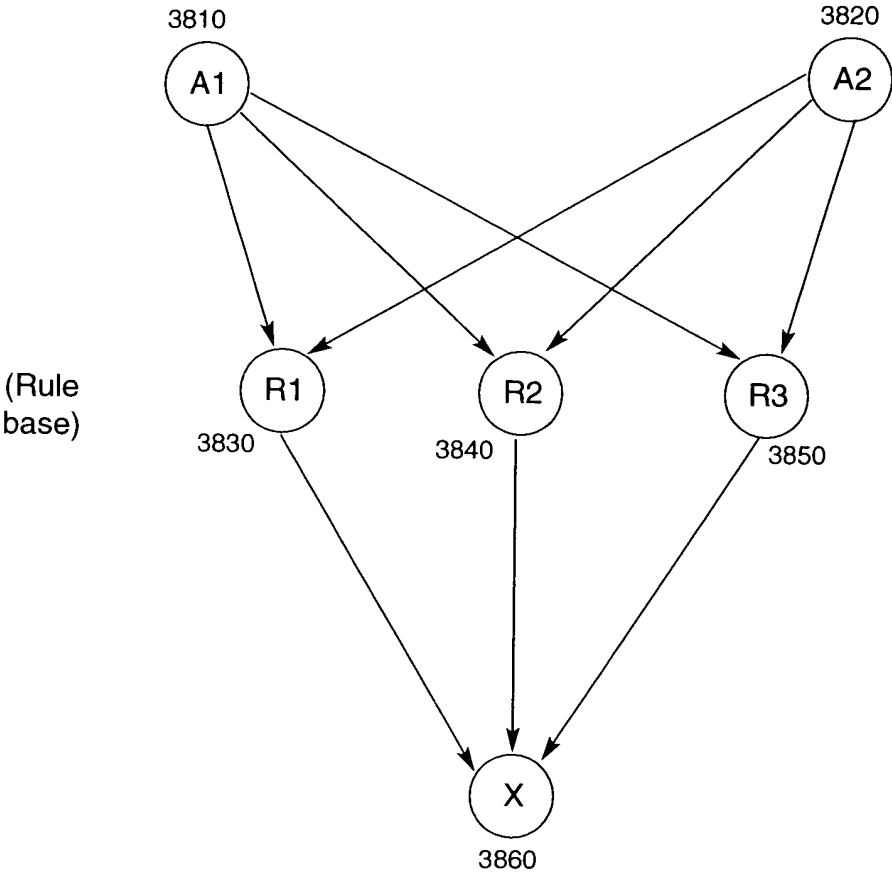


Fig 39: Five Layer Evolving Fuzzy Neural Network

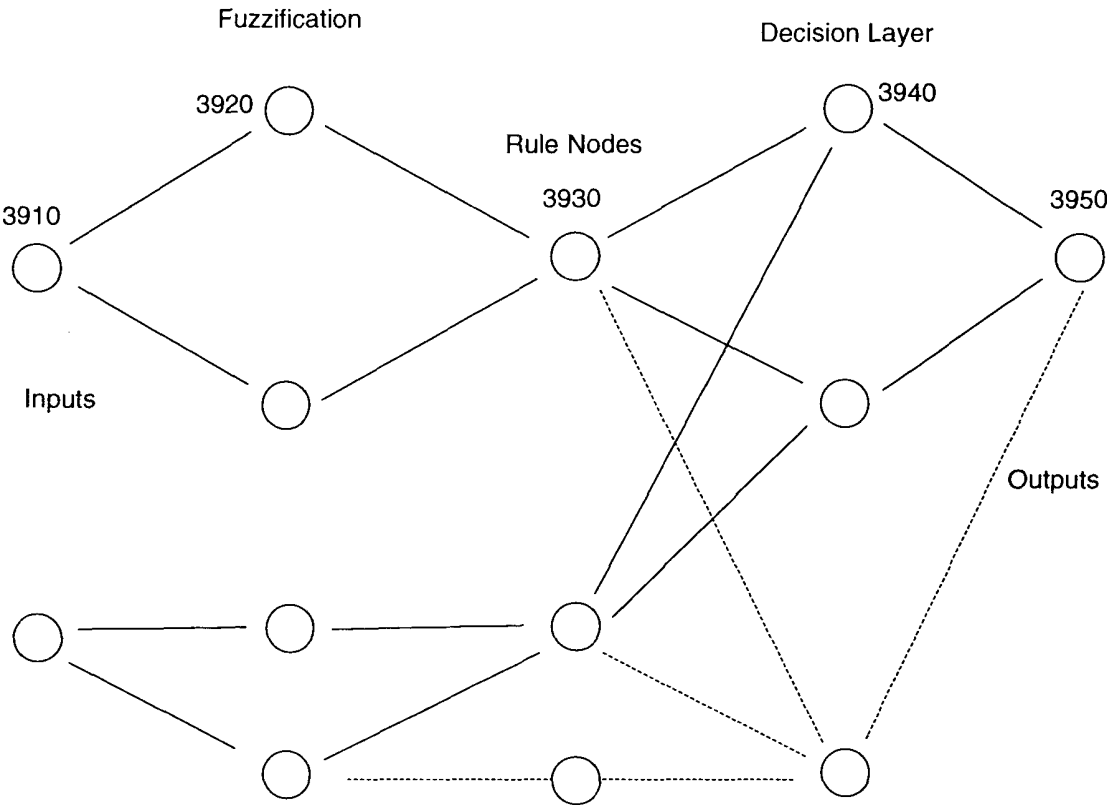


Fig 40: Adaptive Network Based Fuzzy Inference System

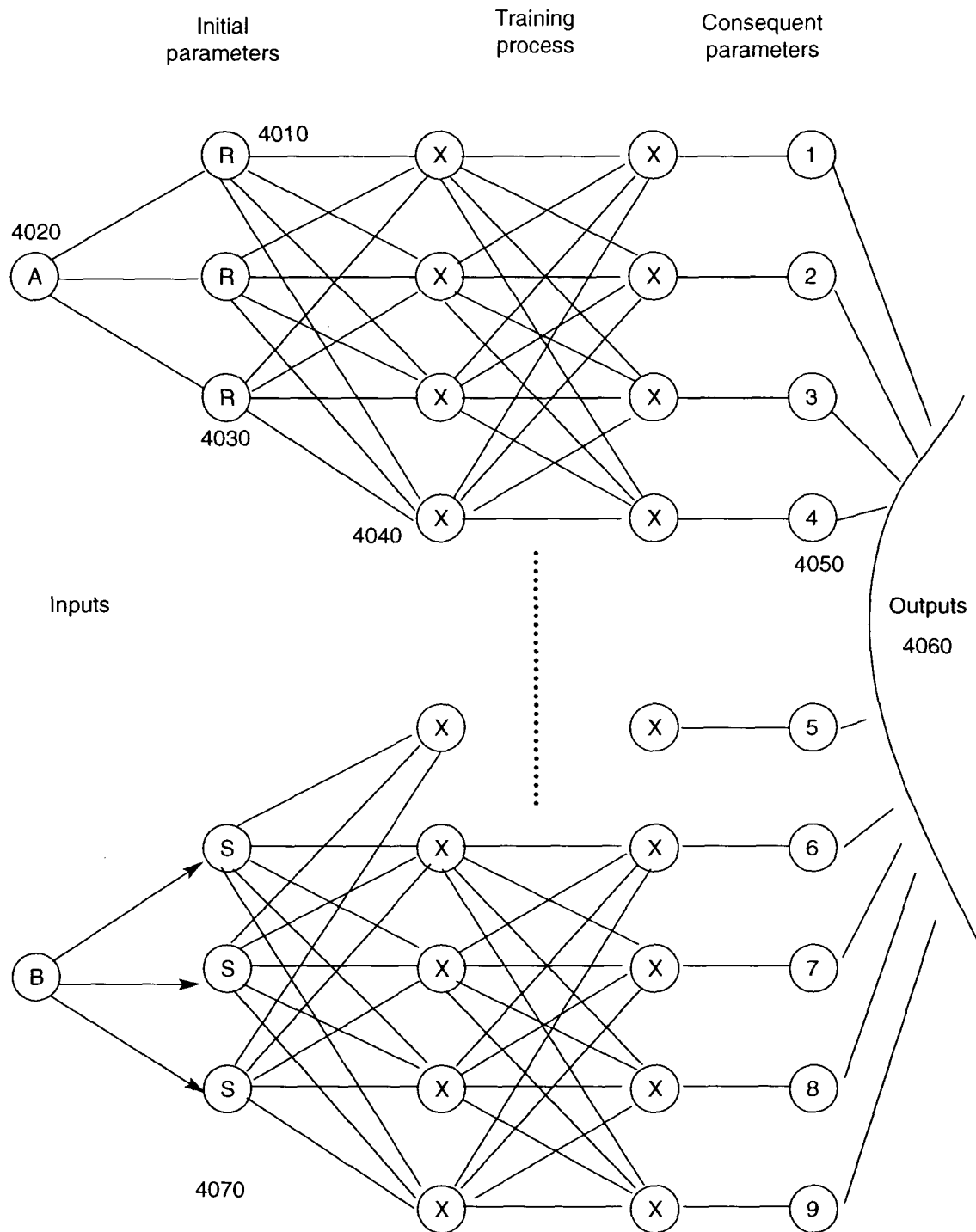


Fig 41: Self Organizing Neural Fuzzy Inference Network Architecture

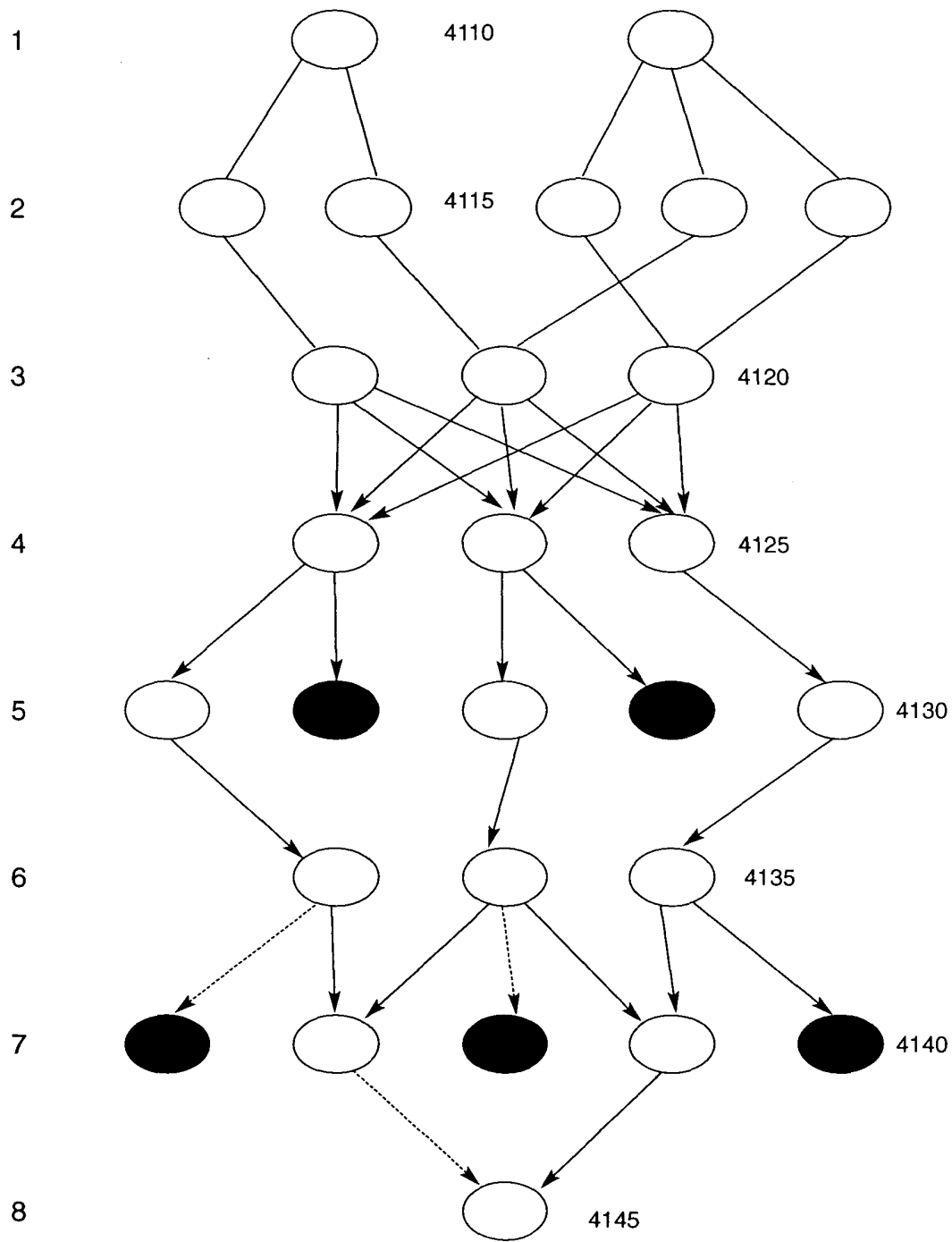
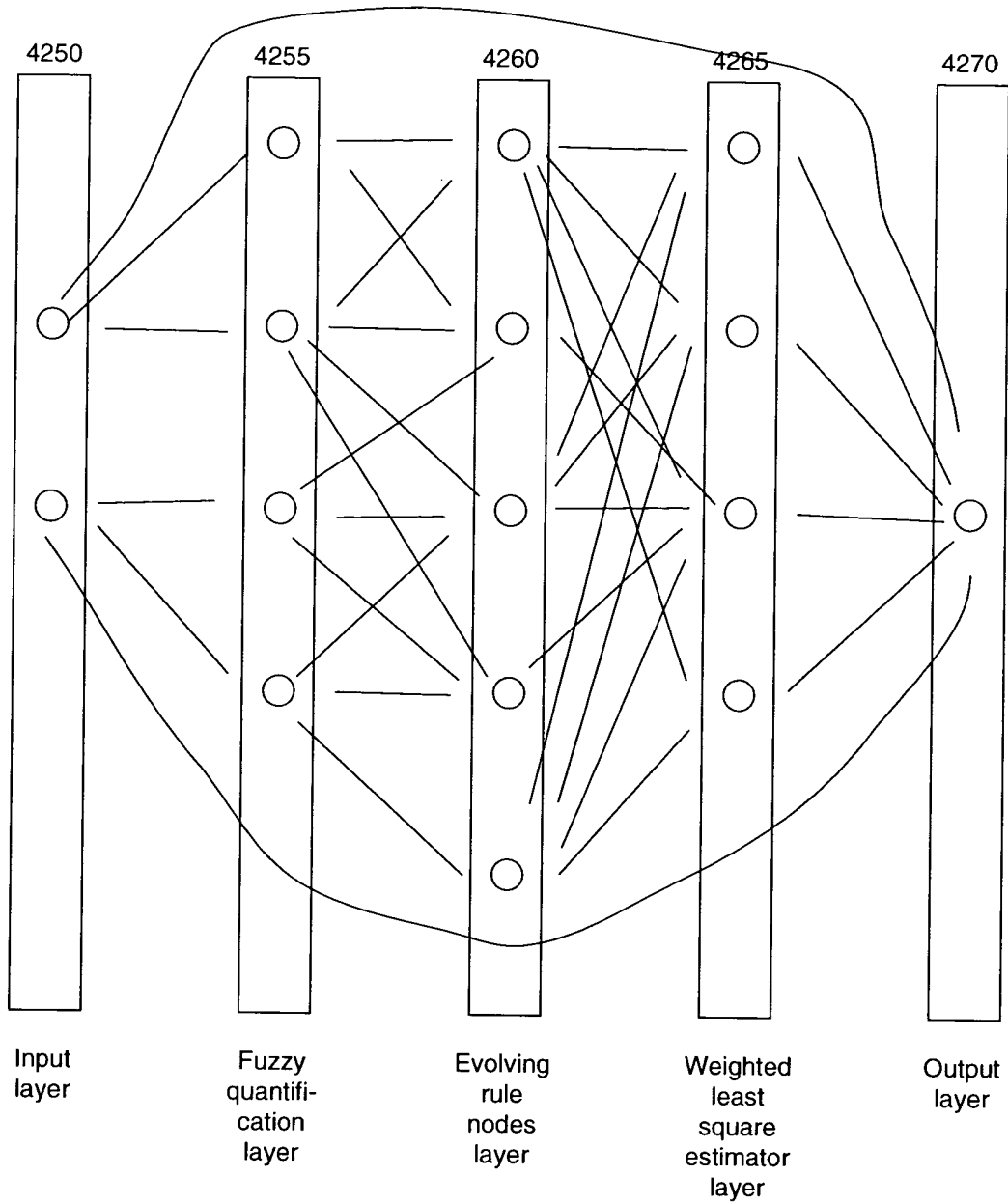


Fig 42: Dynamic Evolving Fuzzy Neural Network



**Fig 43: Flexible Extensible Distributed ANN -
Shared ANN Computation Between MRAs**

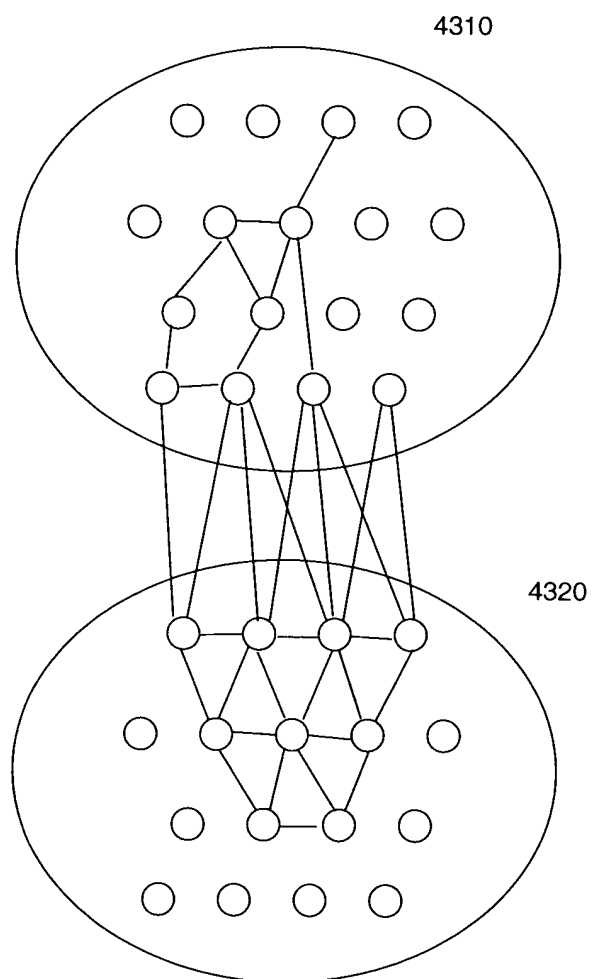


Fig 44: IMSA Dynamics in MAS: MRA Interactions via IMSAs

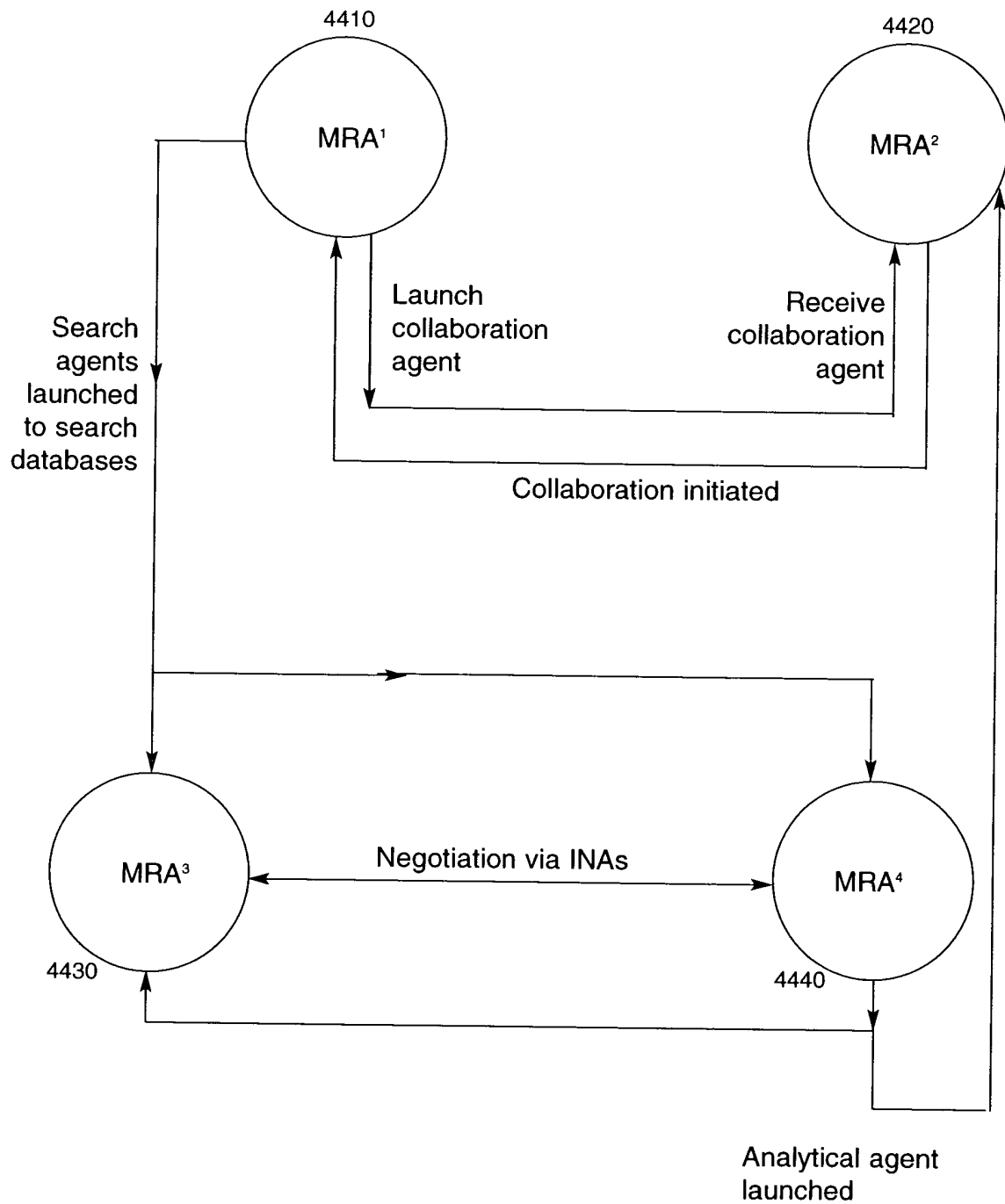


Fig 45: IMSA Relations Between MRAs

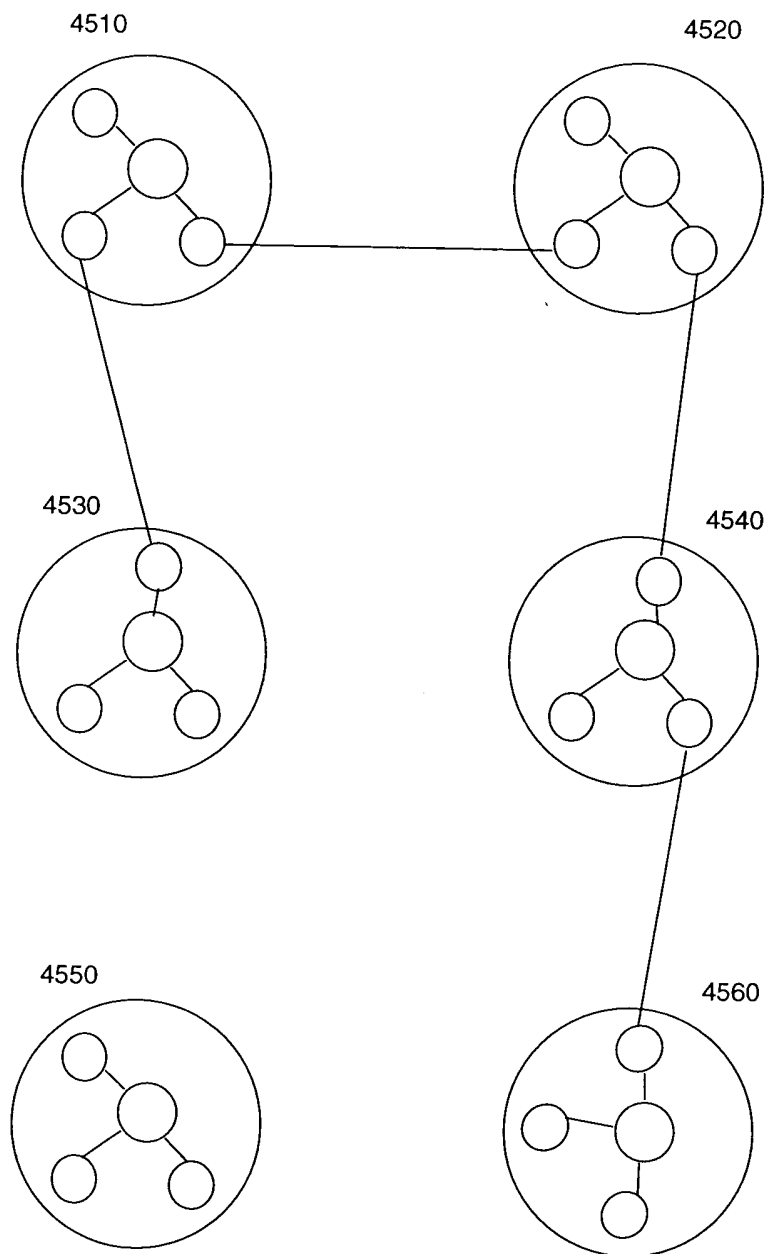


Fig 46: Analytical Agents

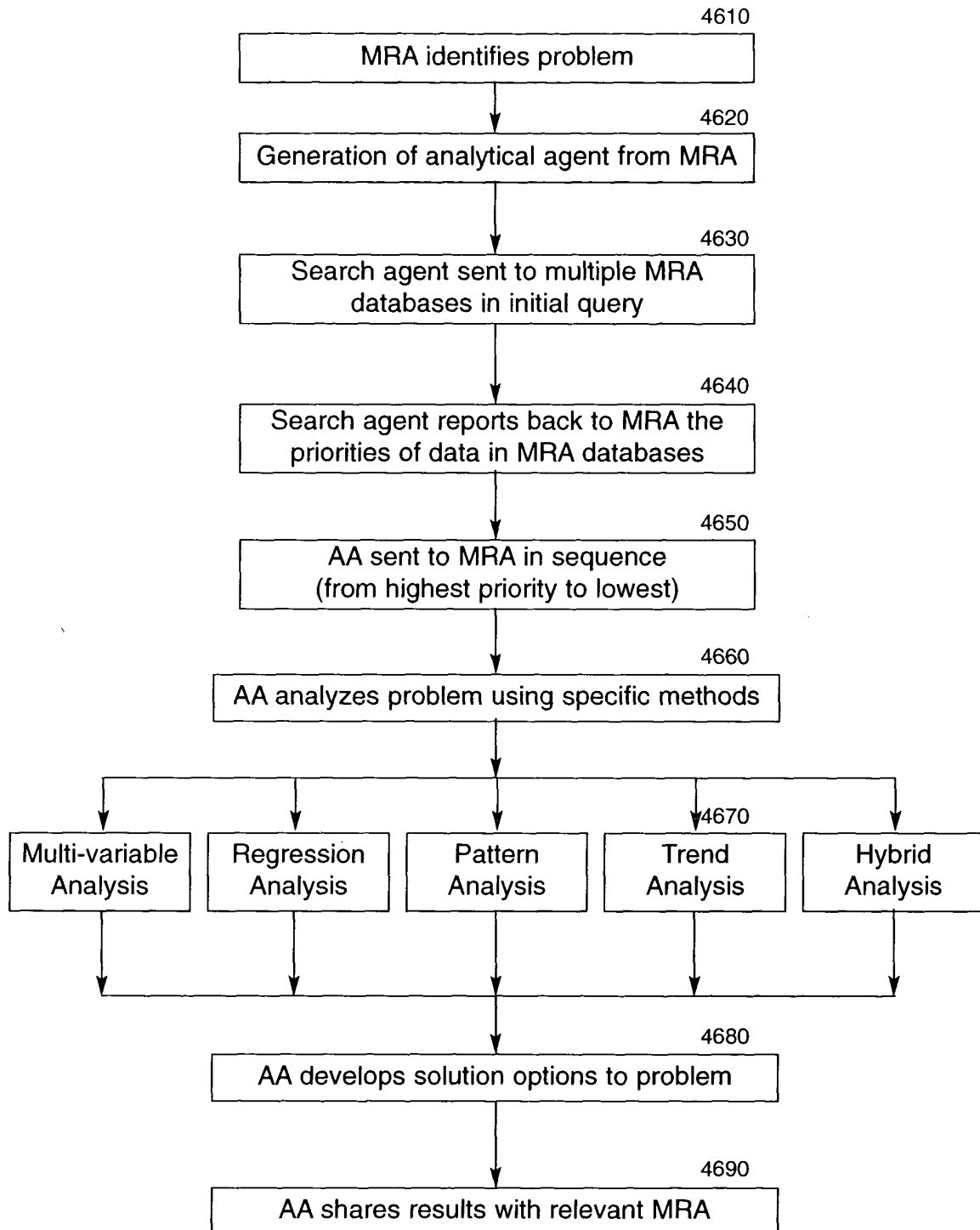


Fig 47: Search Agents

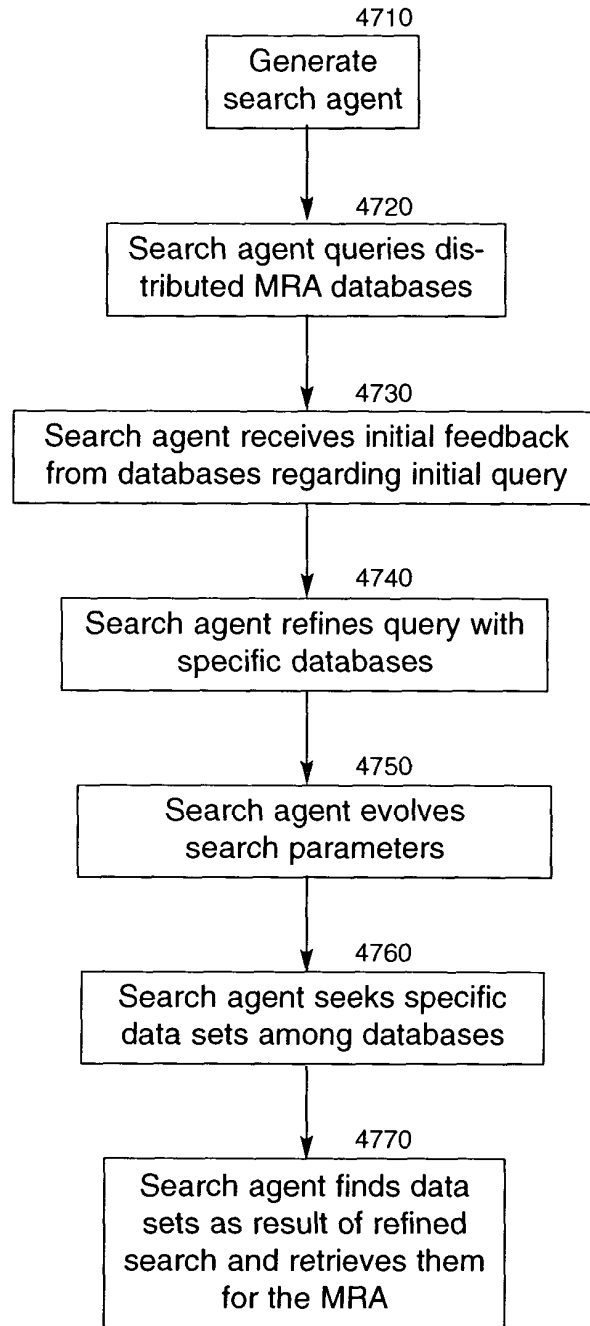


Fig. 48: Intelligent Negotiation Agents

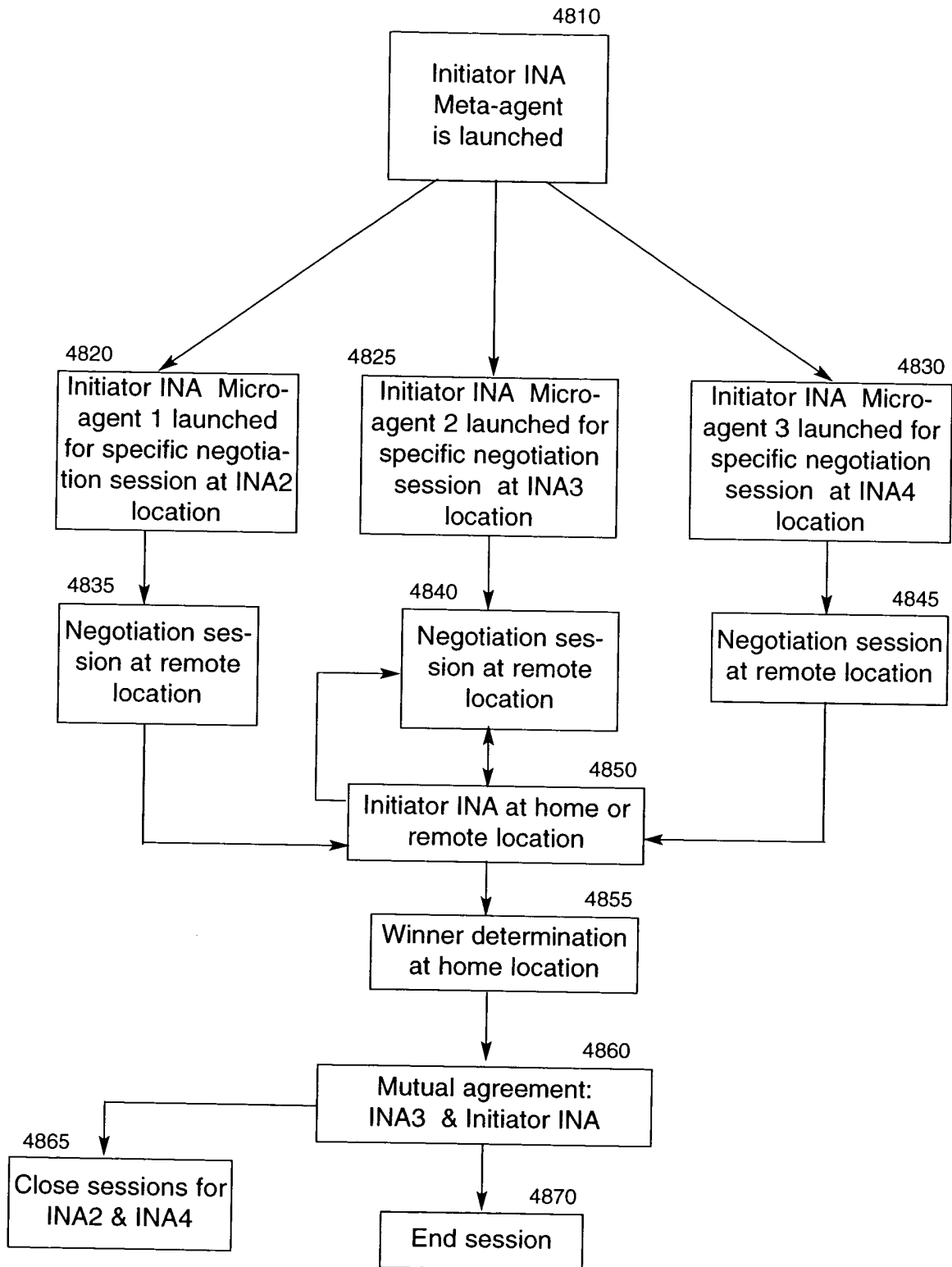


Fig 49: IMSA Intercommunication

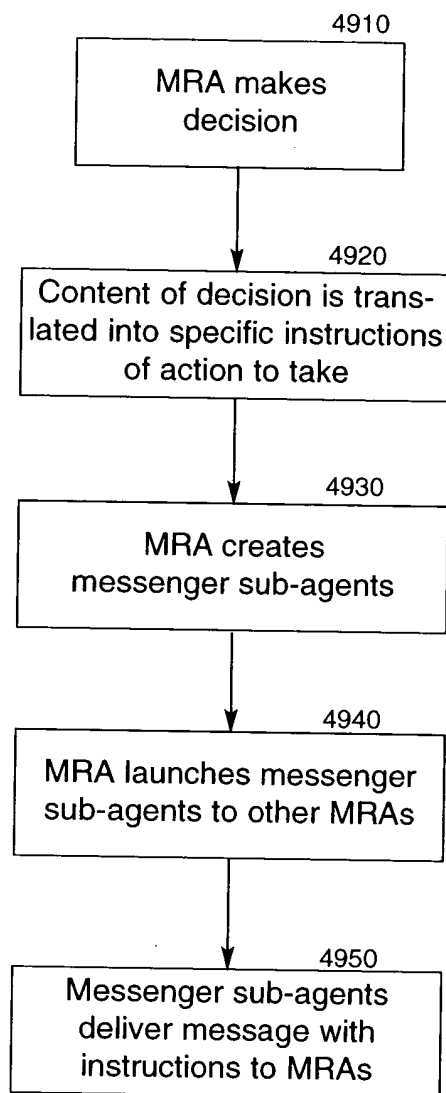


Fig 50: INA Architecture

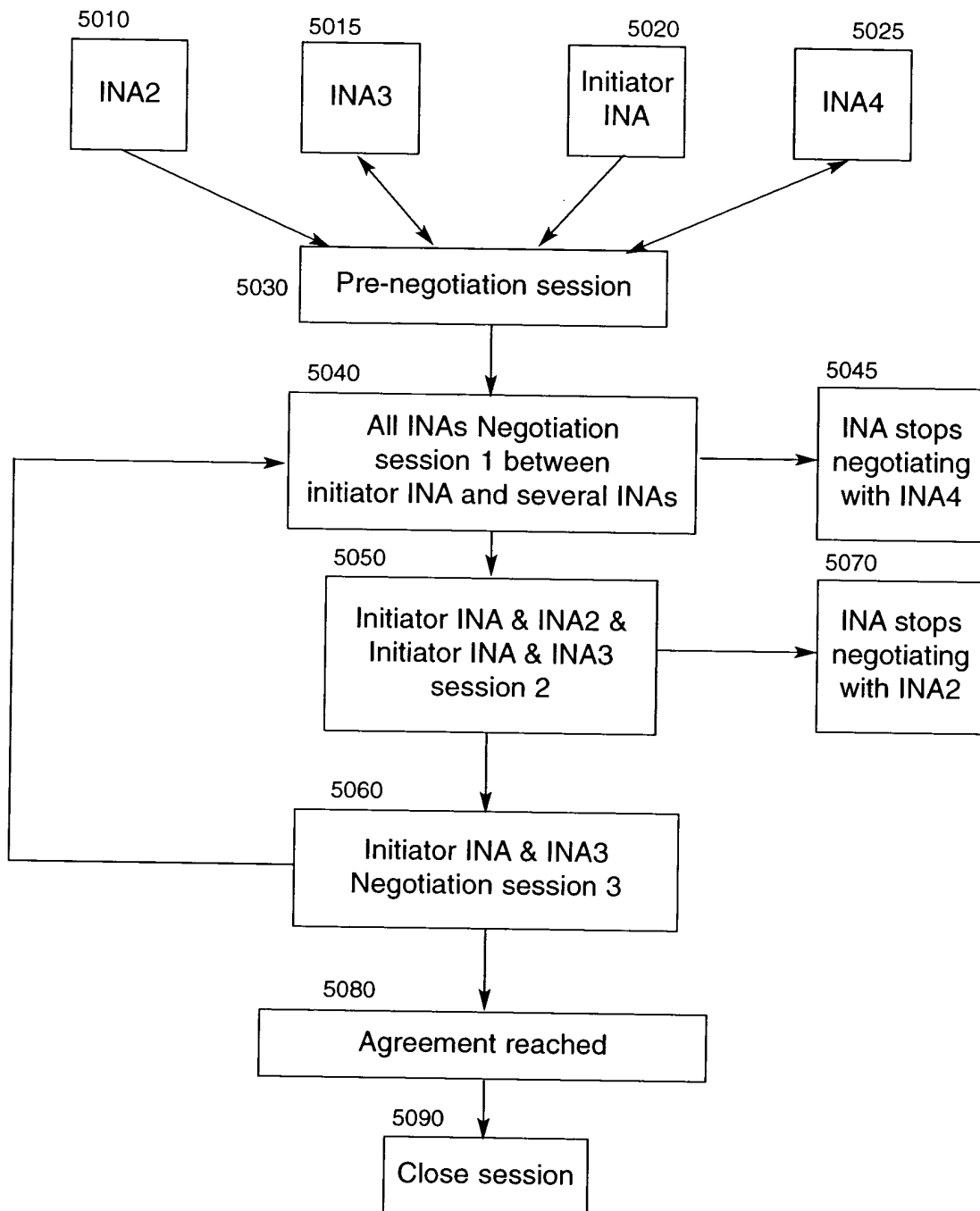


Fig. 51: Pre-Negotiation

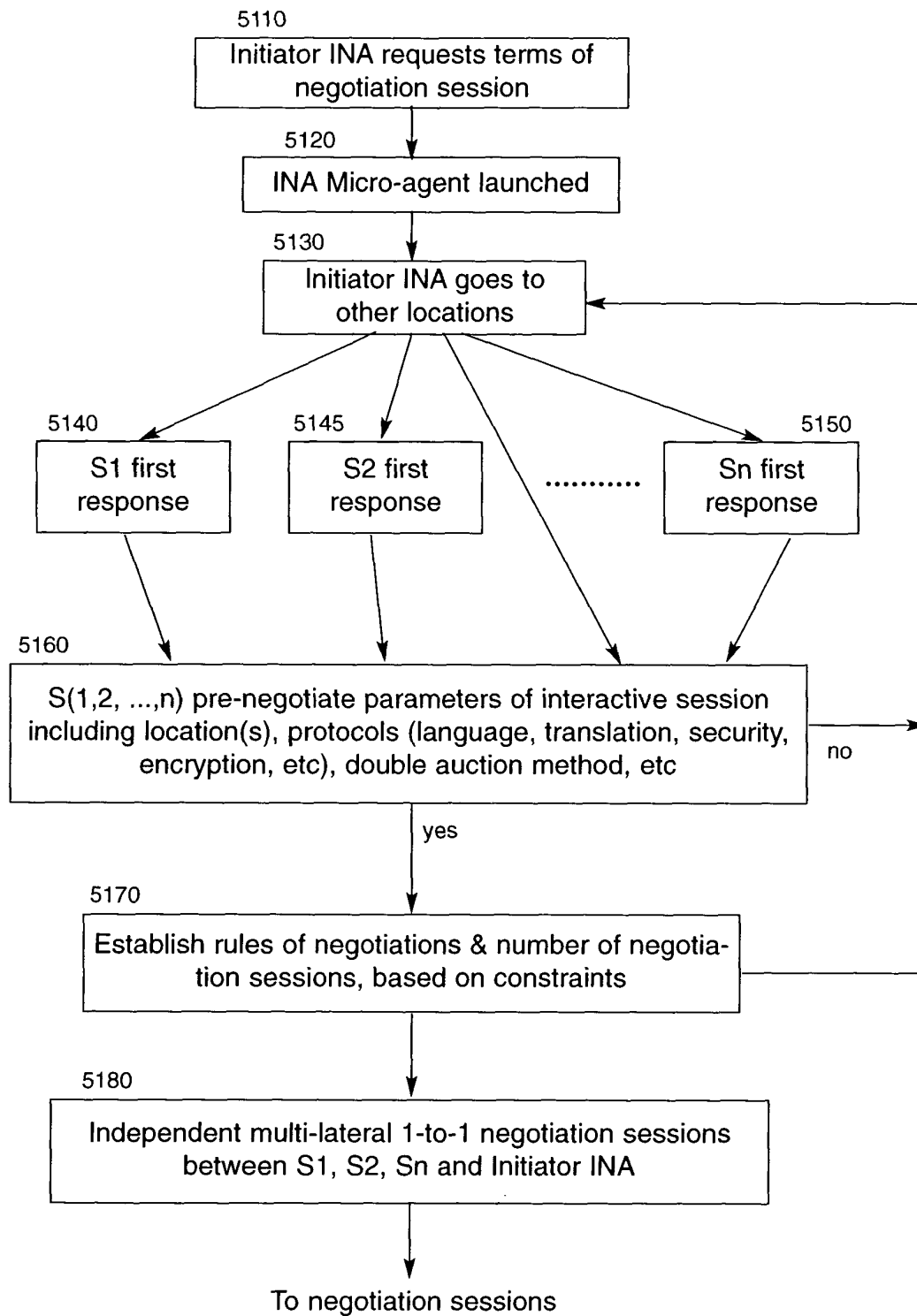


Fig. 52: INA Logistics

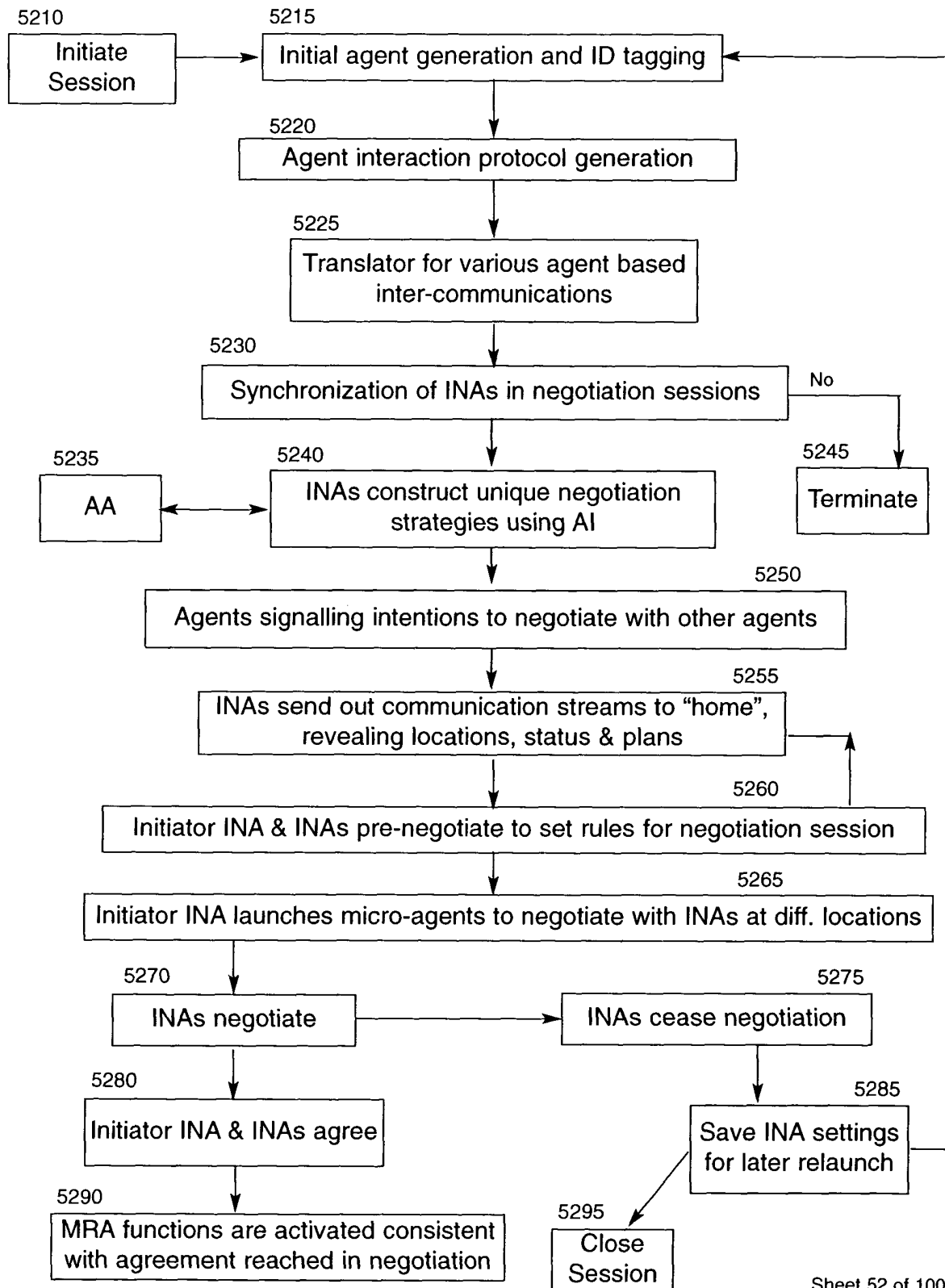
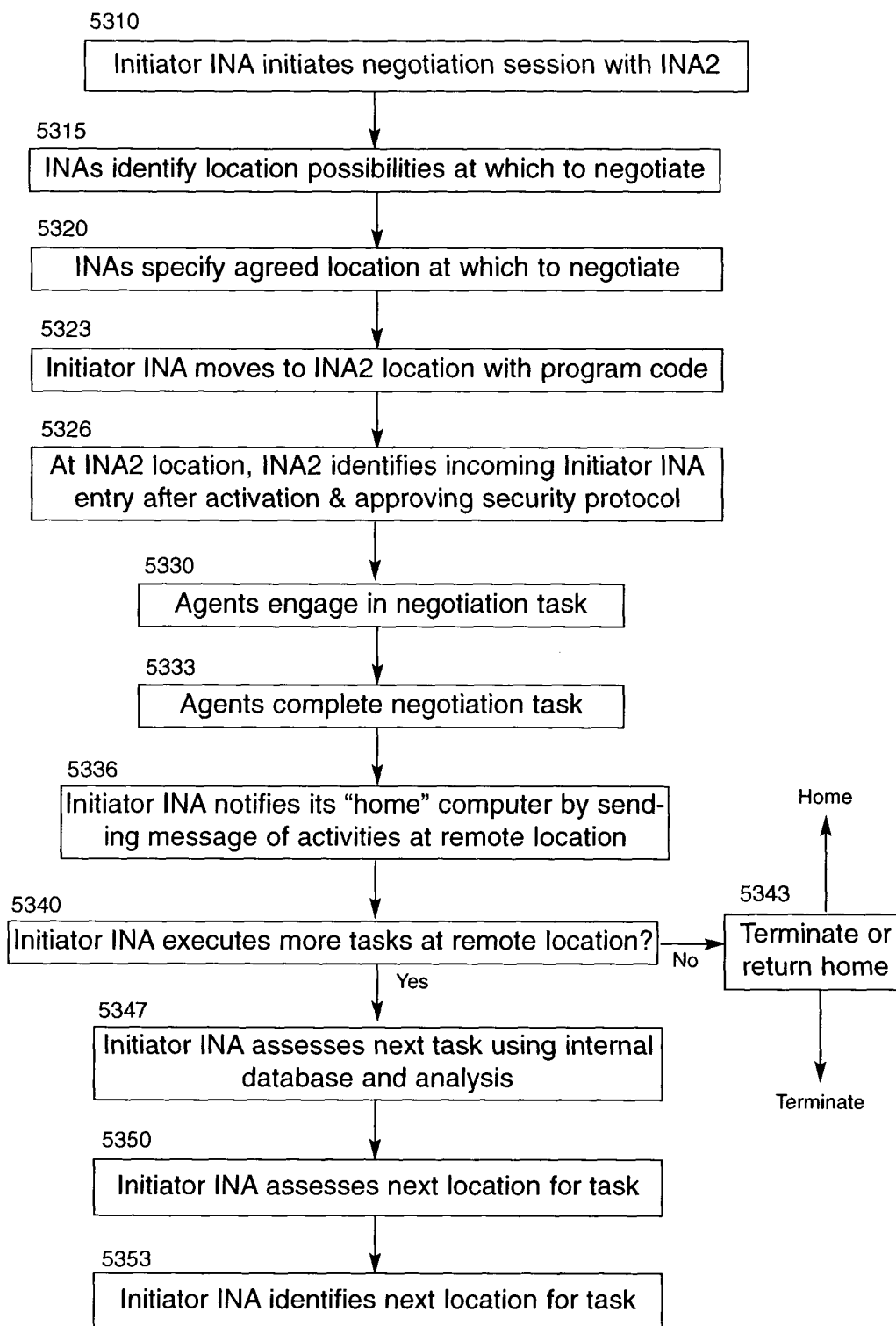


Fig. 53A: Negotiation in a Distributed System with Mobility



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**Fig. 53B: Negotiation in a Distributed System with Mobility
(Continued)**

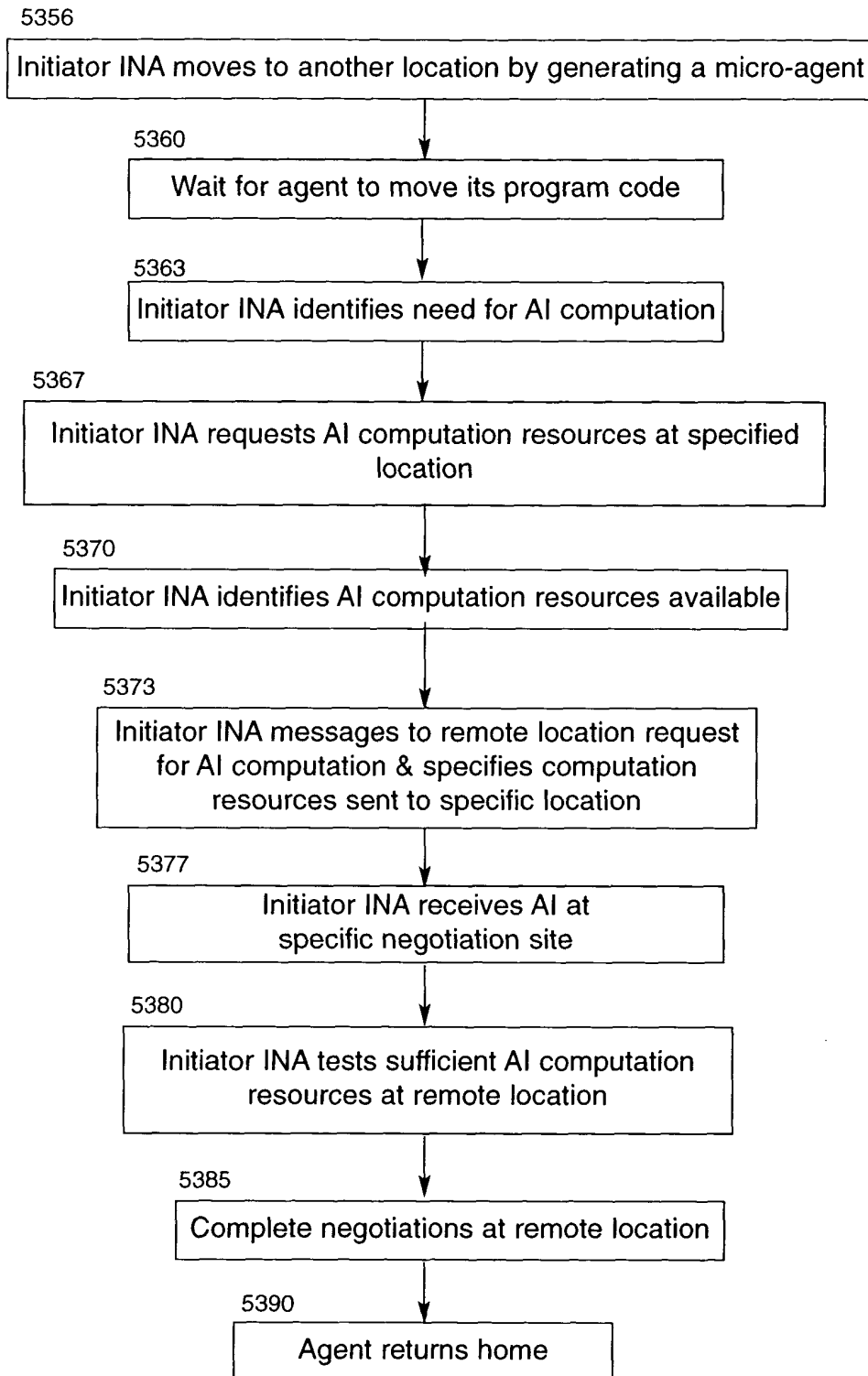


Fig 54: Simultaneous Multi-lateral Negotiation Process with Multiple Variables

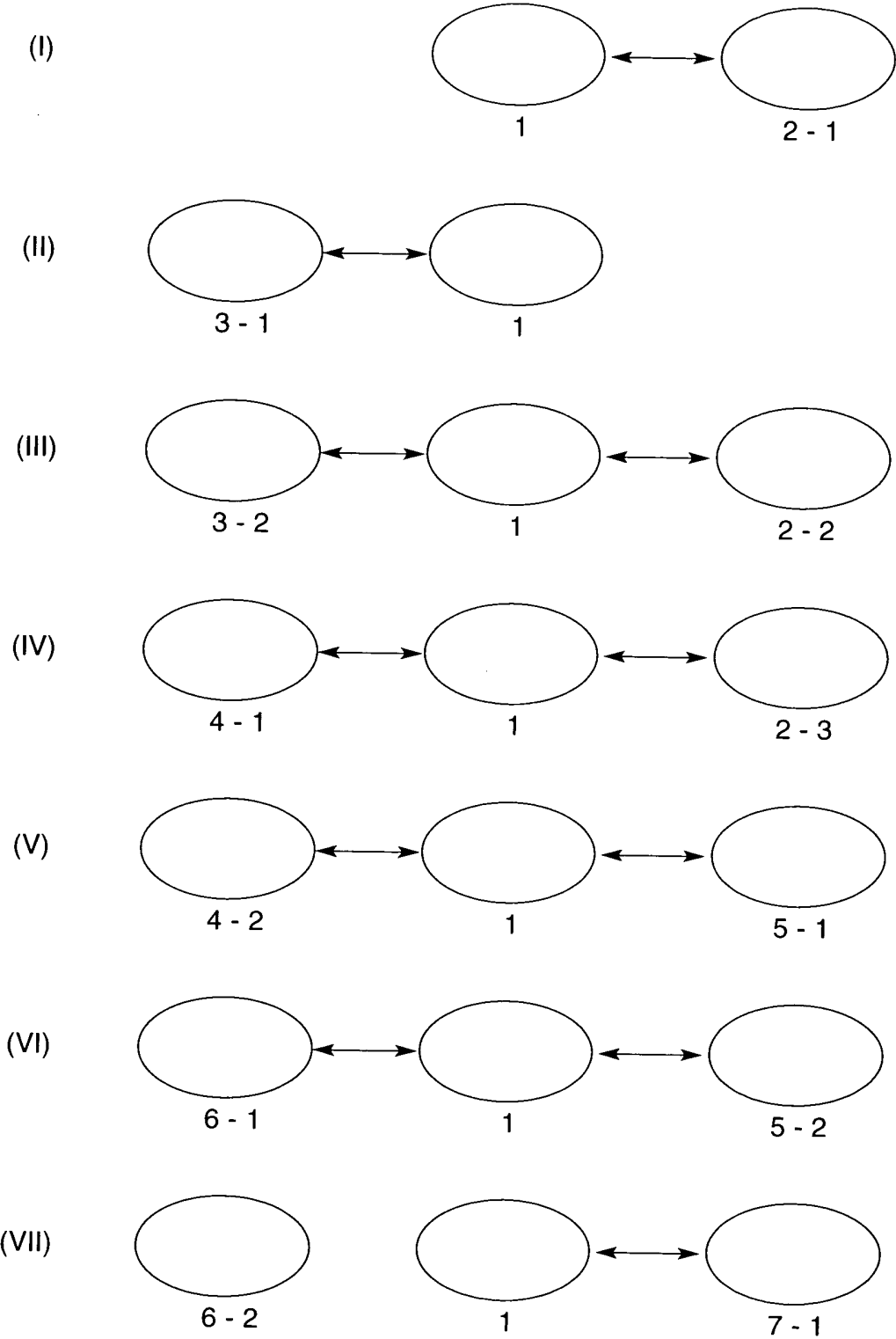


Fig 55: Multivariate Negotiation Factors

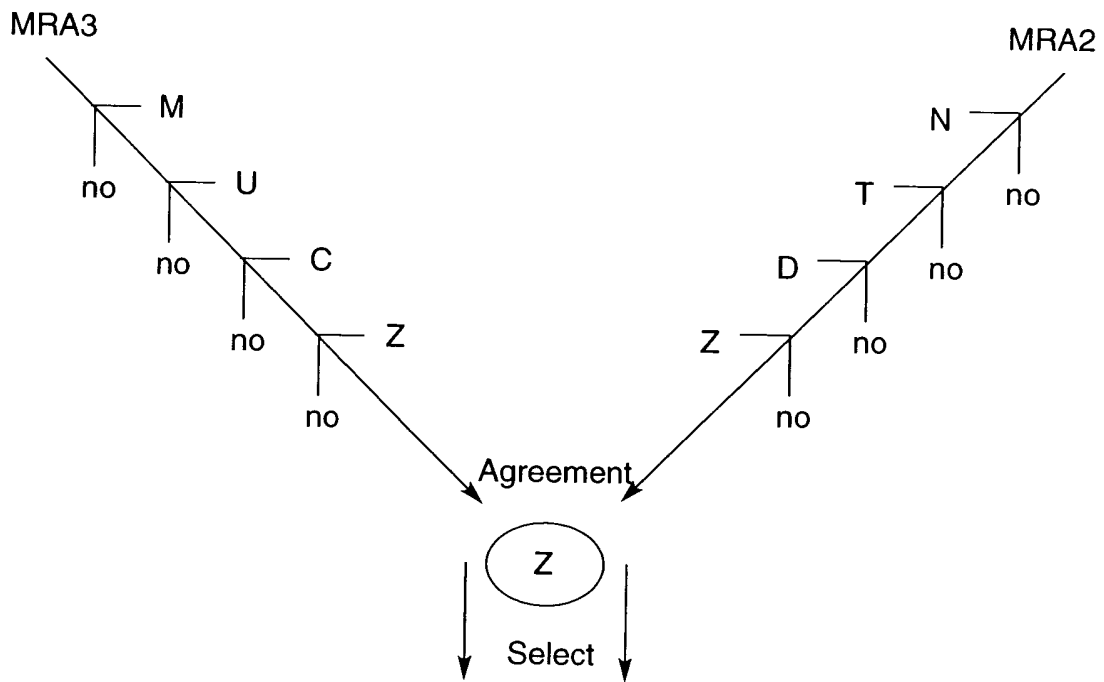
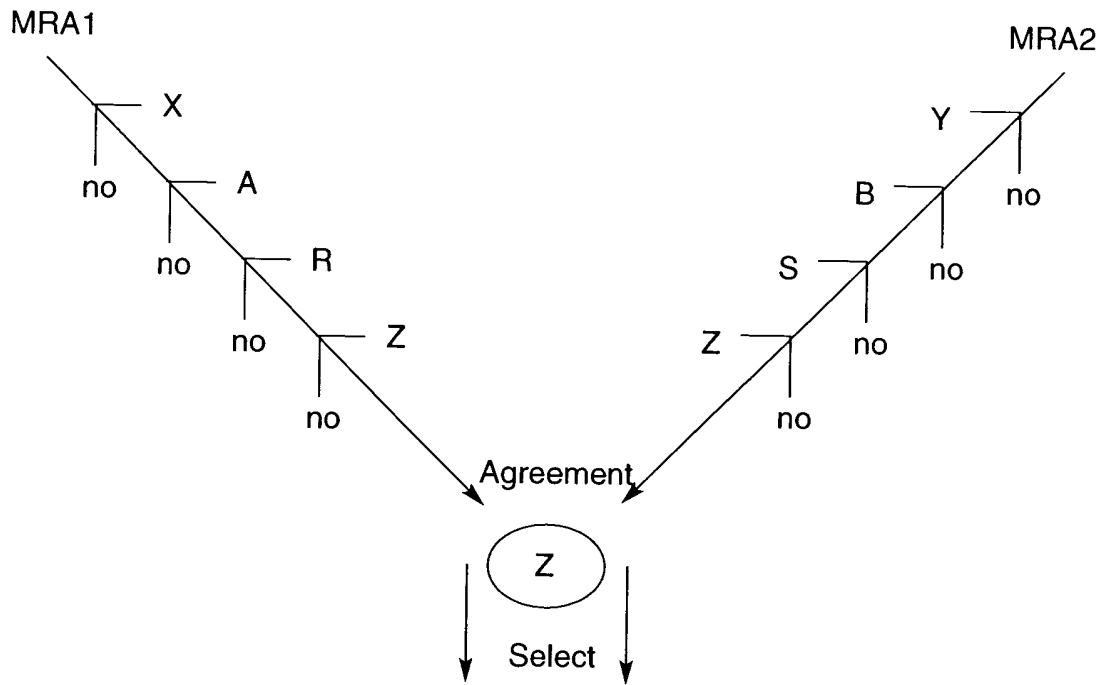


Fig. 56: Winner Determination in Competitive INA Framework

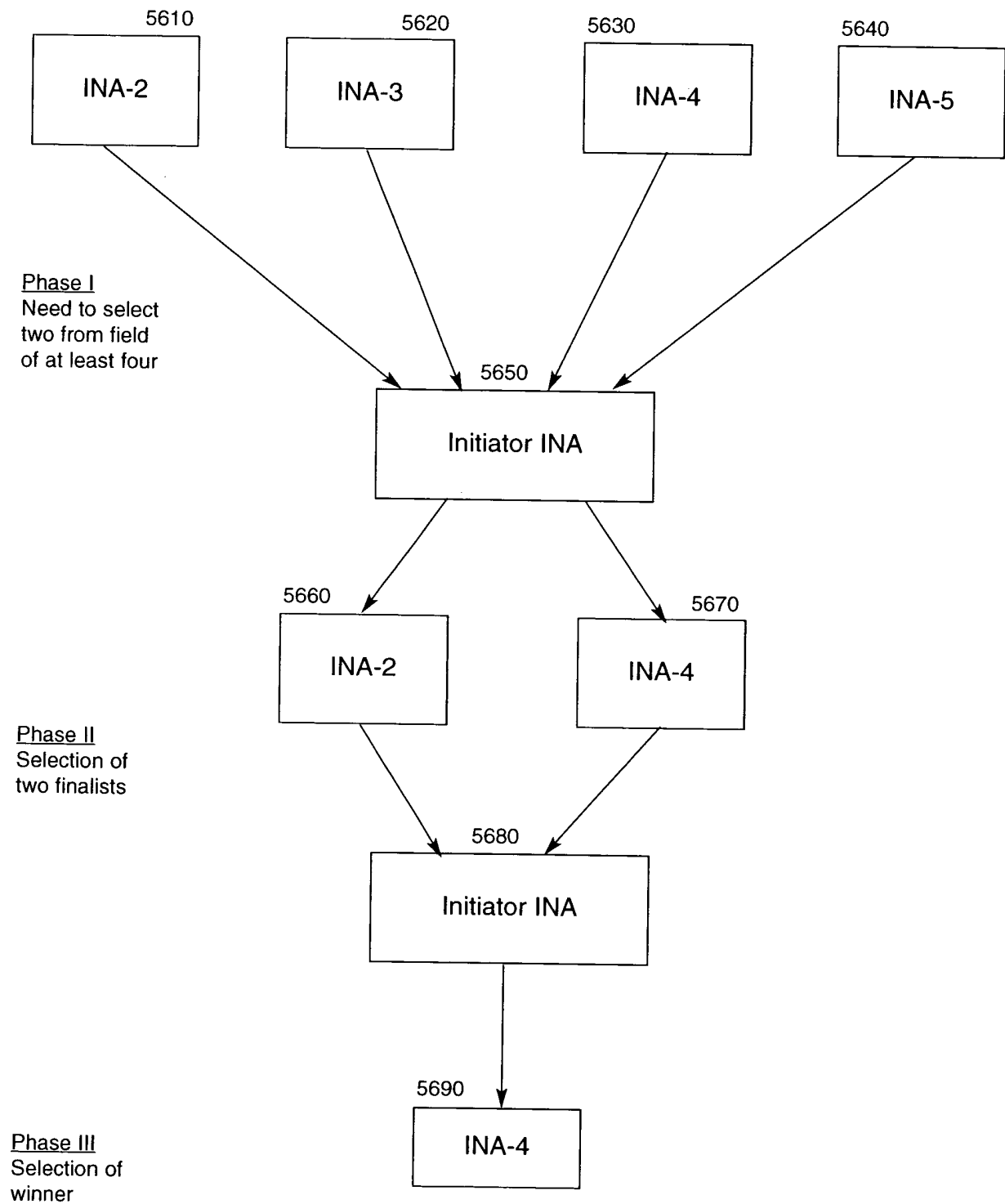


Fig 57: Argumentation Process

| Temporal Phases | 5710 A | 5720 B | 5730 |
|------------------------------------|-----------|-----------|------|
| Negotiation variables | | | X |
| Prune out uncompromise variable | X | | |
| Prune out variables non-negotiable | | | X |
| Compromise key variables | X | | X |

Fig 58: Anticipating Opposing INA Strategies

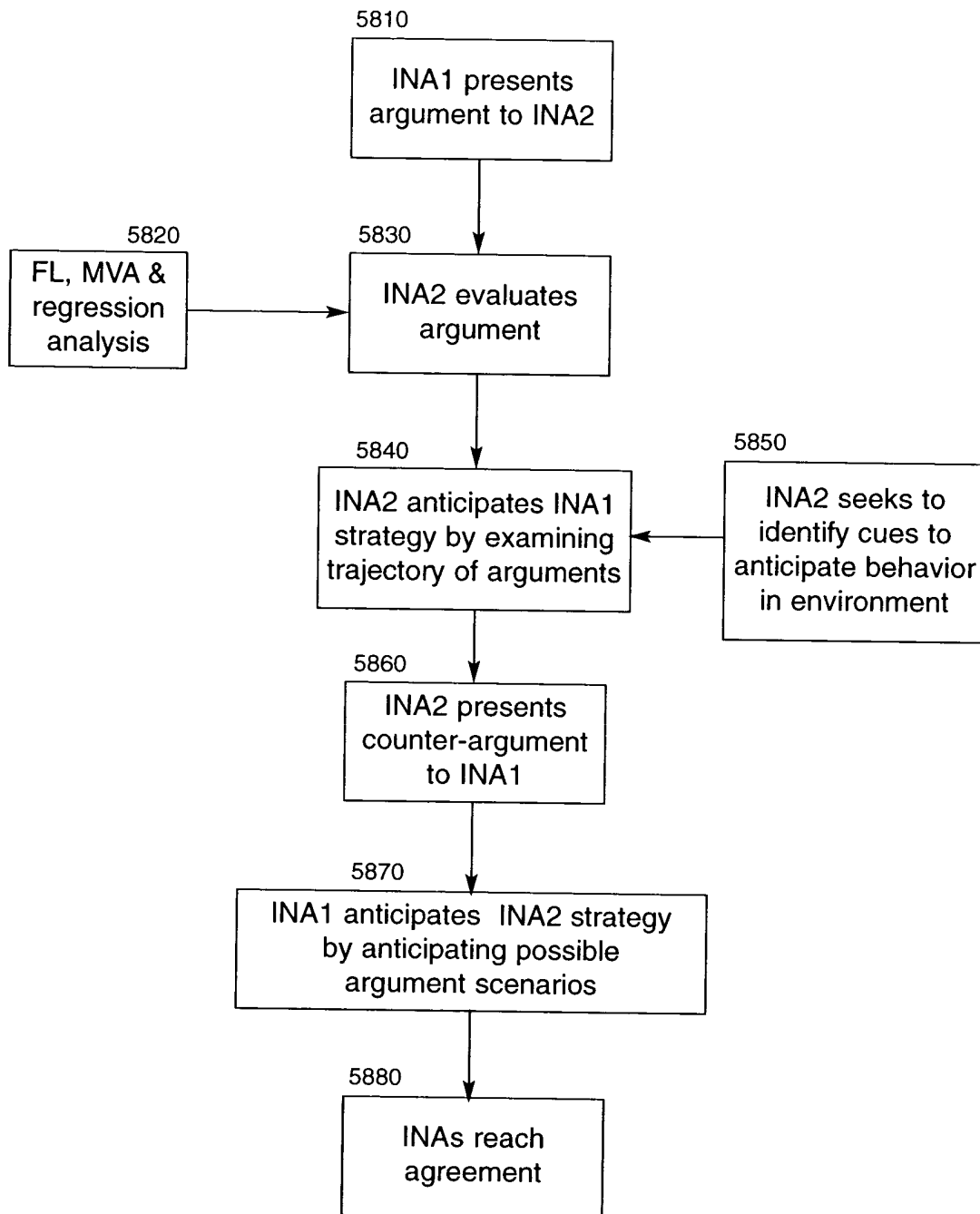


Fig 59: Identify Problems: Group Agrees To Narrow Focus

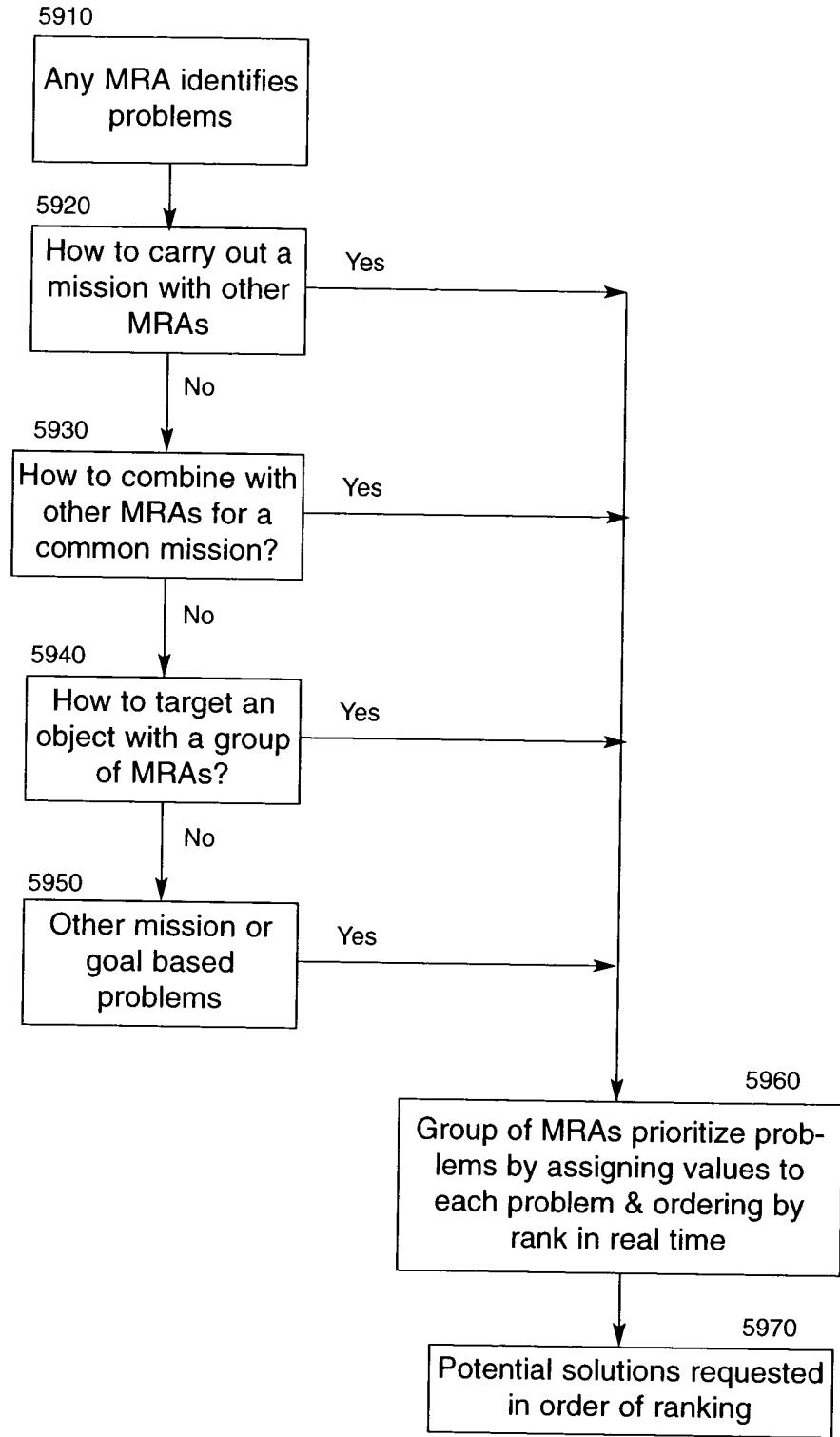


Fig 60: Develop Solution Options Between MRAs

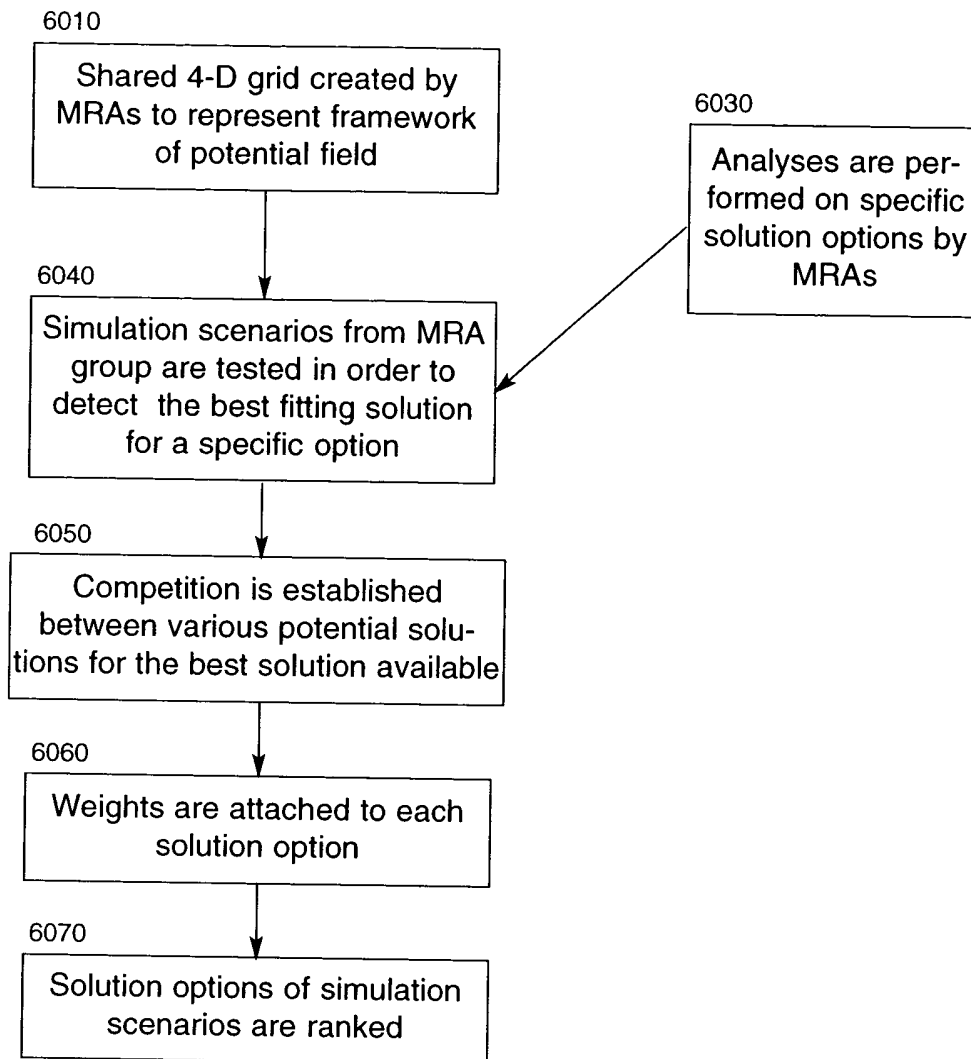


Fig 61: Solution Option Selection Method

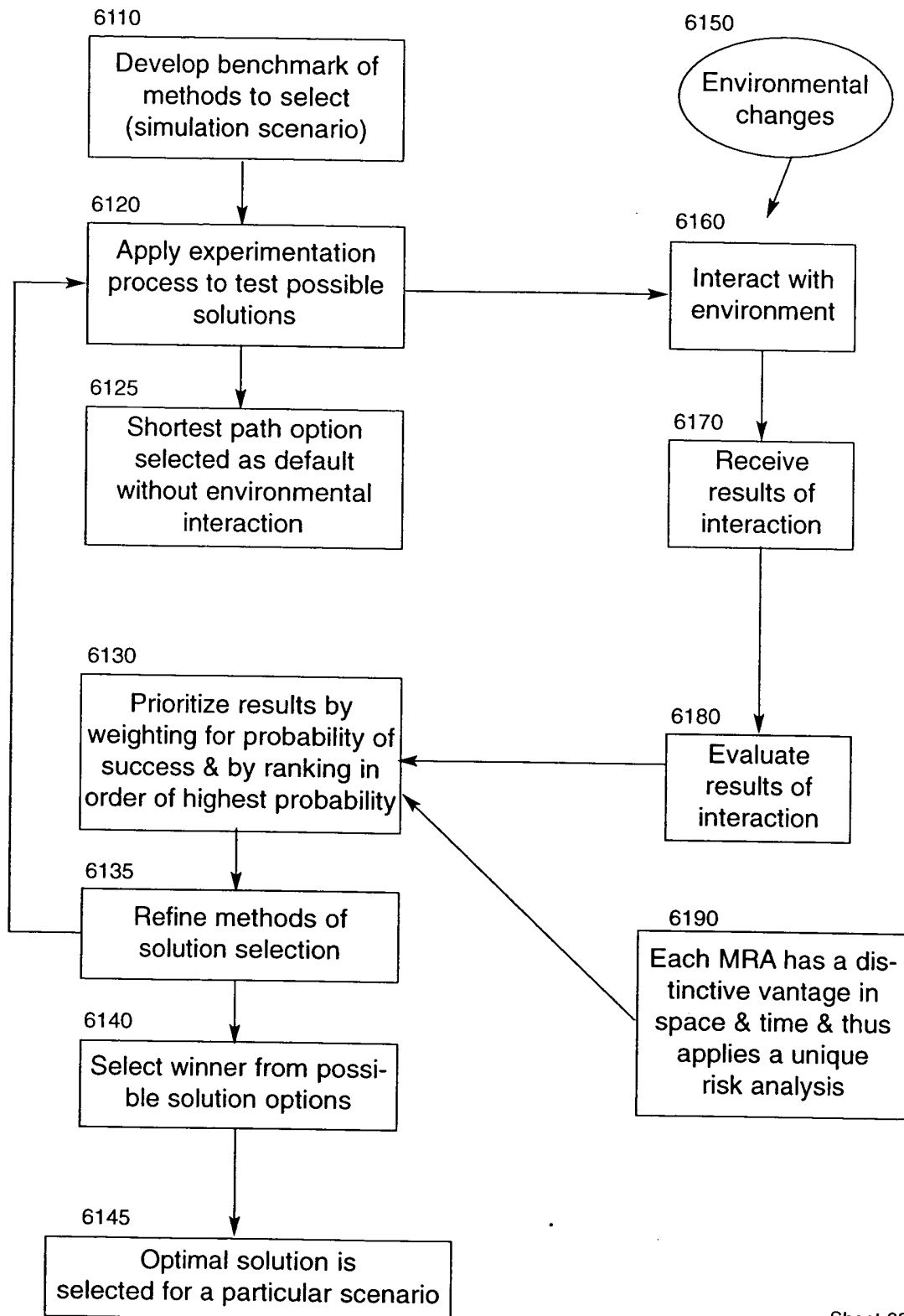


Fig 62: MRAs Select Best Available (not Optimum) Solution To Problem in Present Circumstance While Waiting For Most Recent Relevant Information

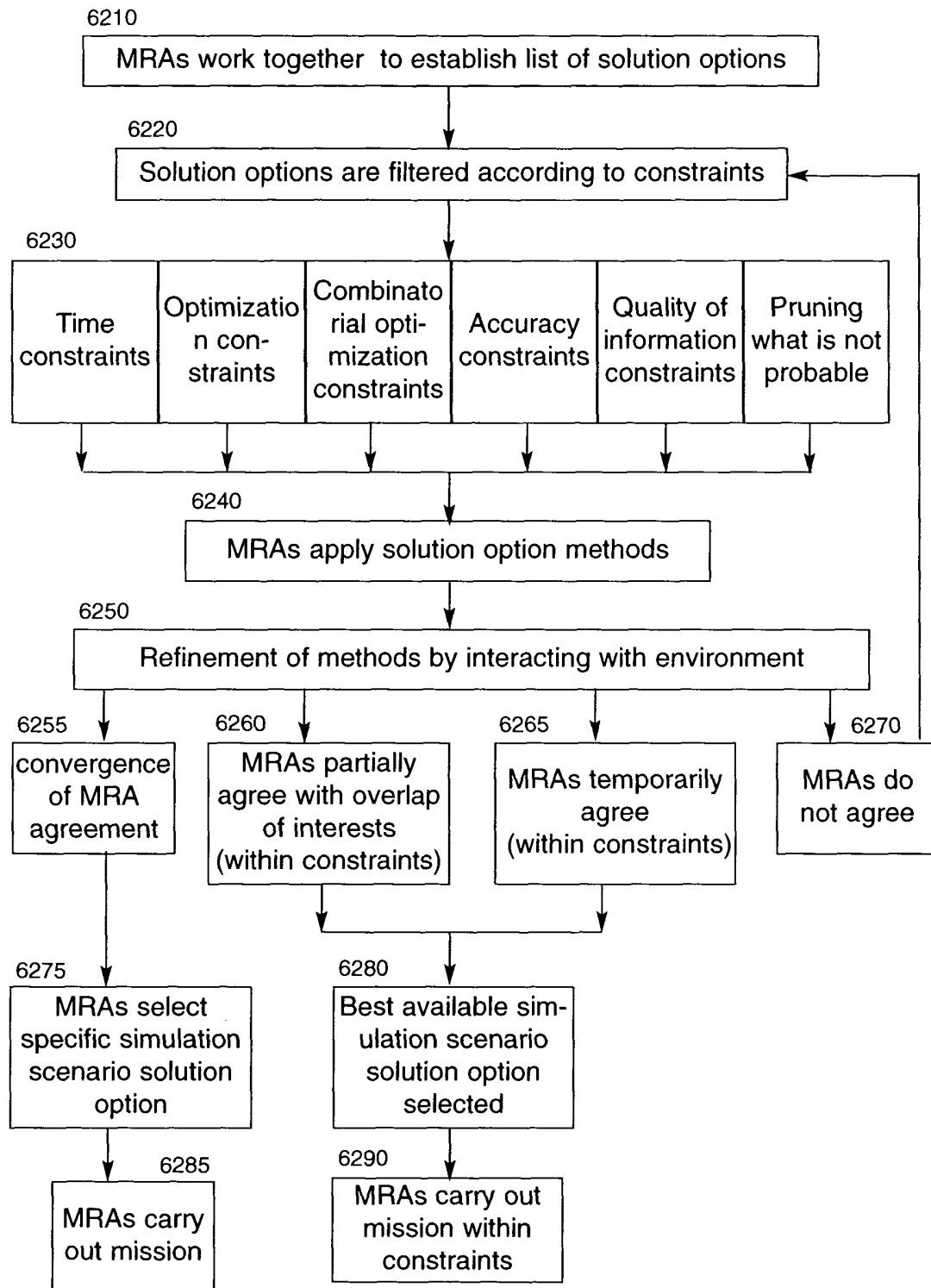


Fig 63: MRA Group Agreement

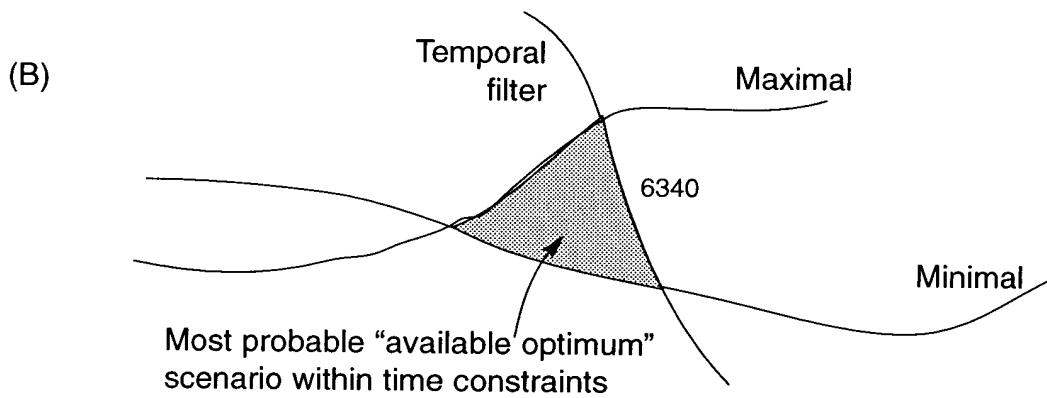
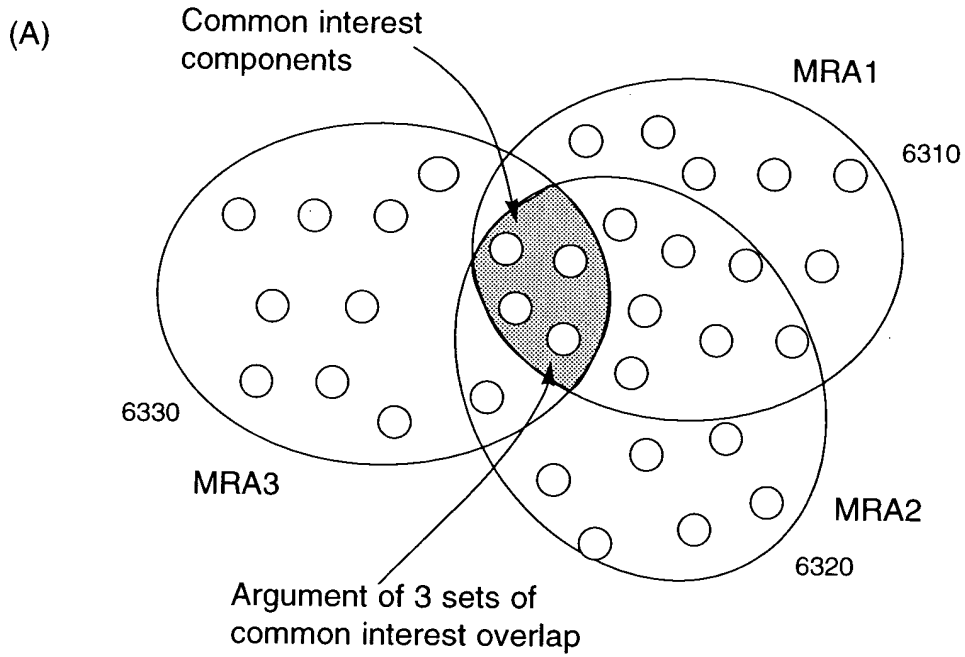


Fig 64: Temporal Aspect of Decision Process

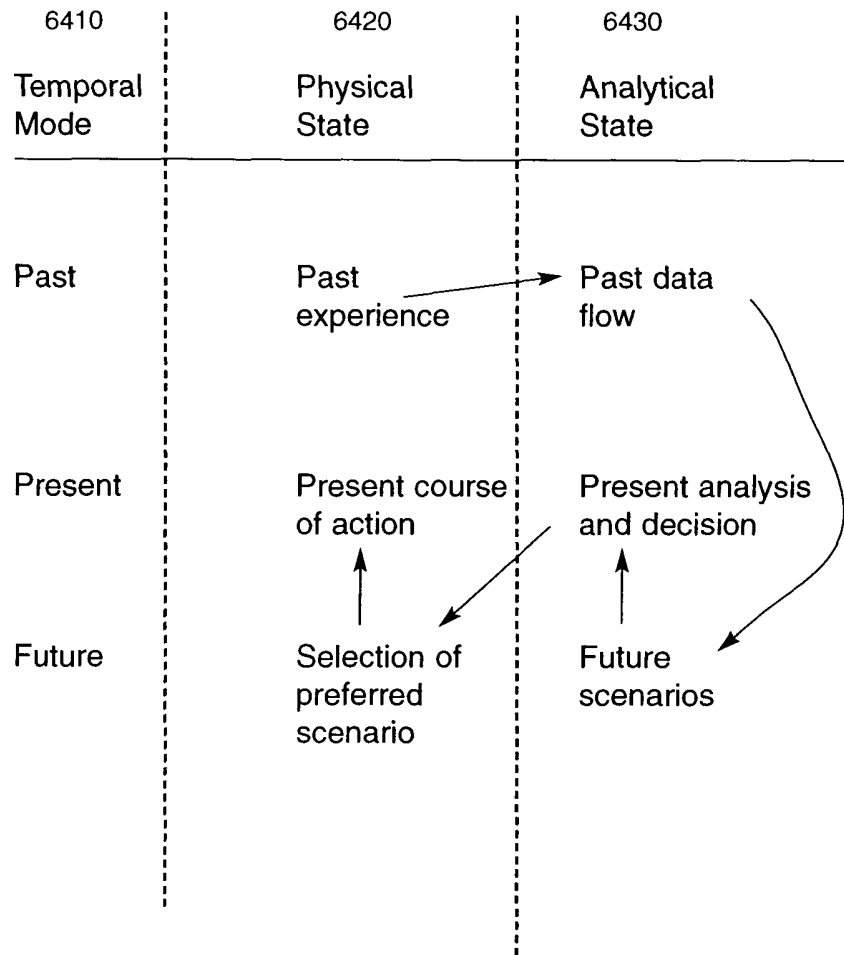


Fig 65: Applying Multivariate Analysis to Problem Solving

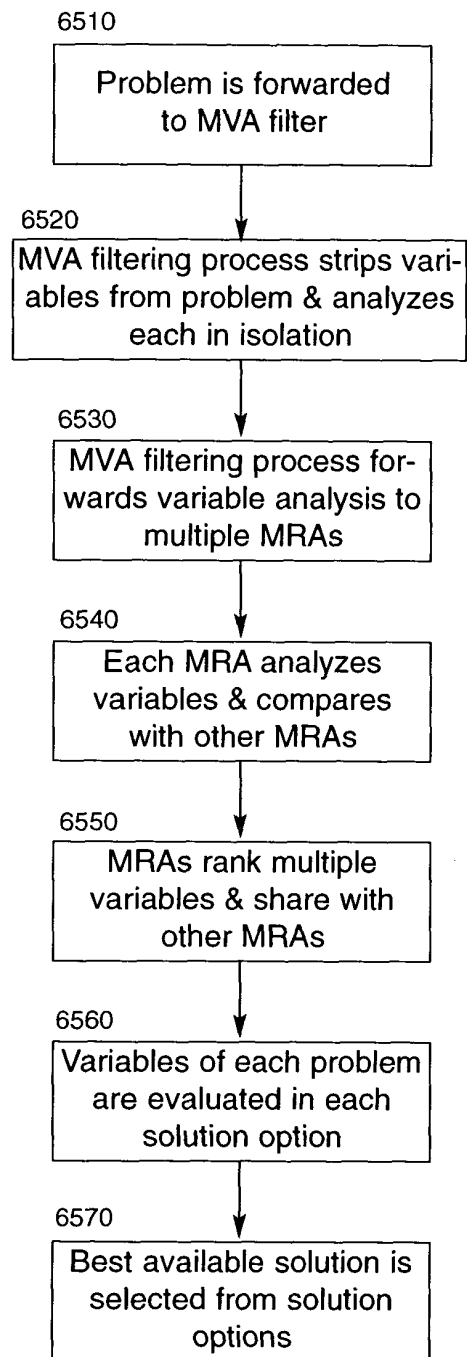


Fig 66: Applying Regression Analysis to Problem Solving of Conflicting MRAs for Winner Determination

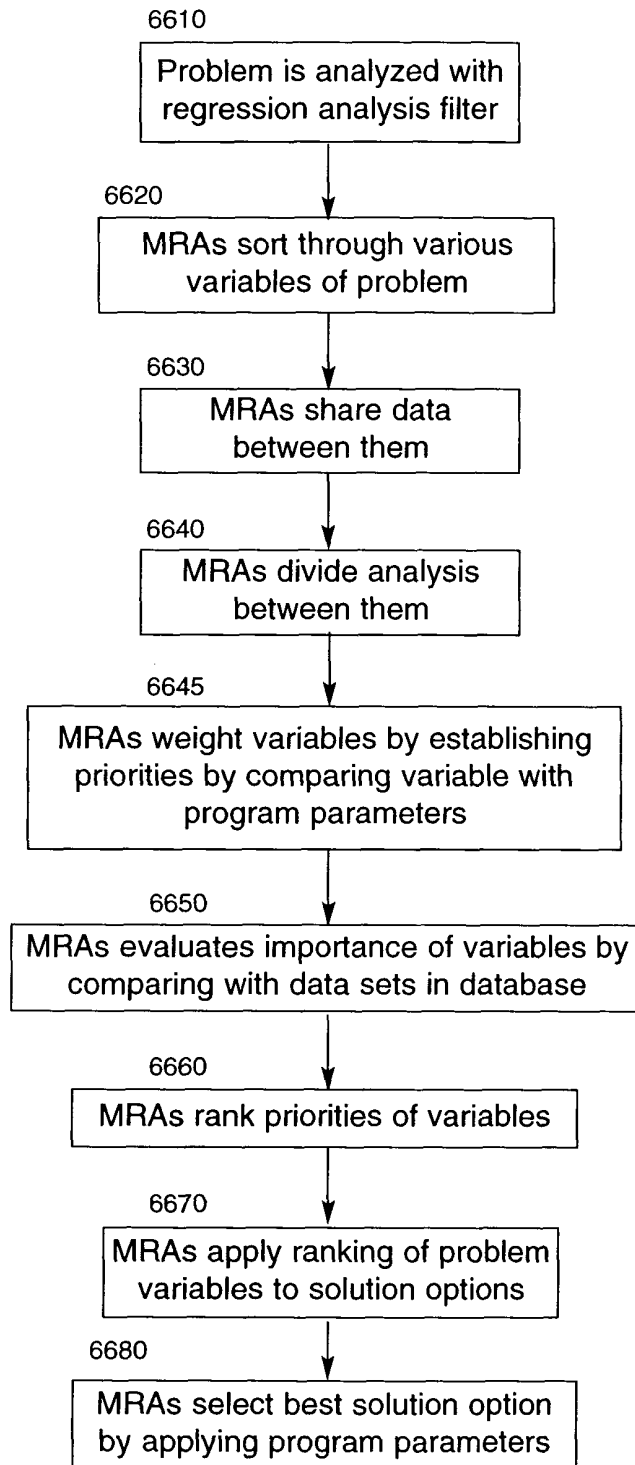
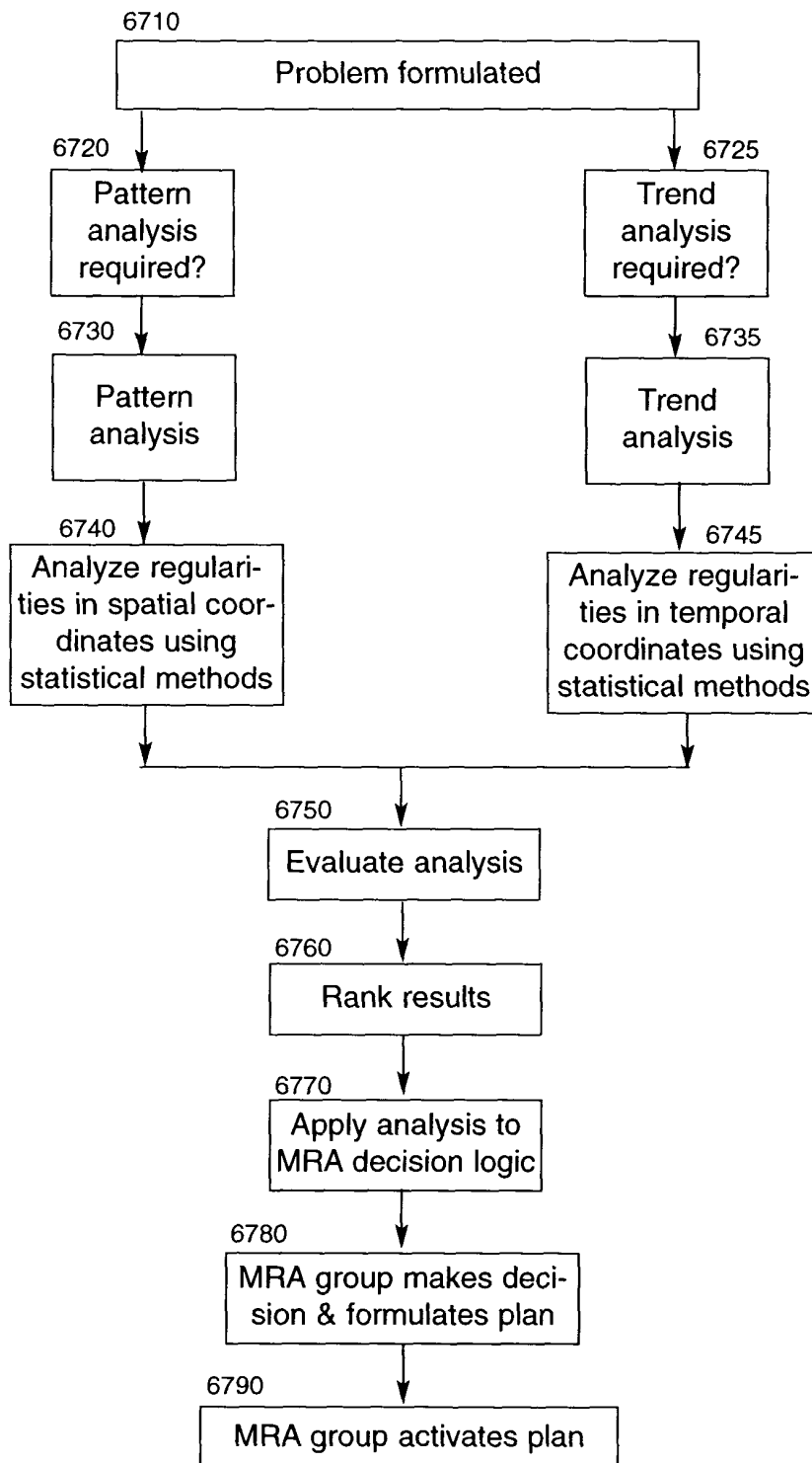
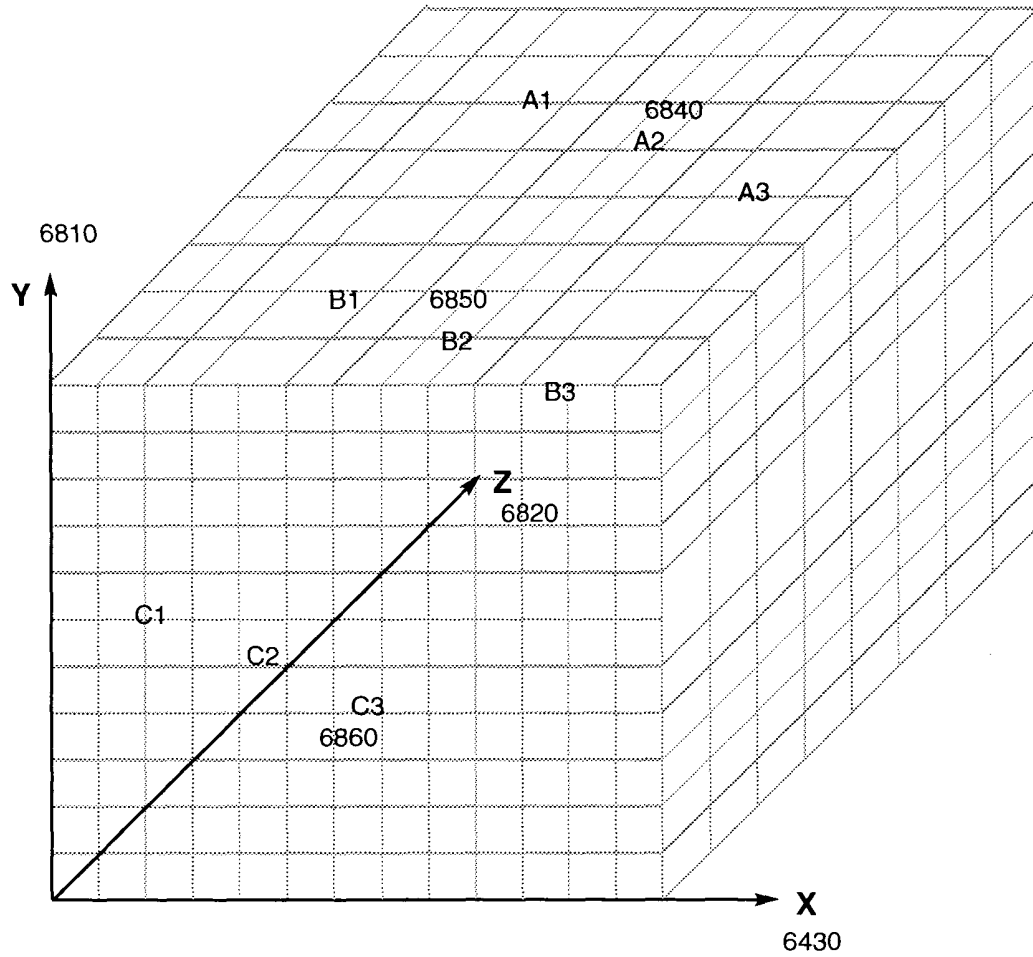


Fig 67: Applying Pattern Analysis and Trend Analysis to Problem Solving of Conflicting MRAs for Winner Determination



**Fig 68: Modeling MRS Activity with Simulations-
Situation Assessment**



MRAs A, B, C move from place 1 to place 3 in a cubic space

Fig 69: Synchronizing Simulations Within MRA Cluster

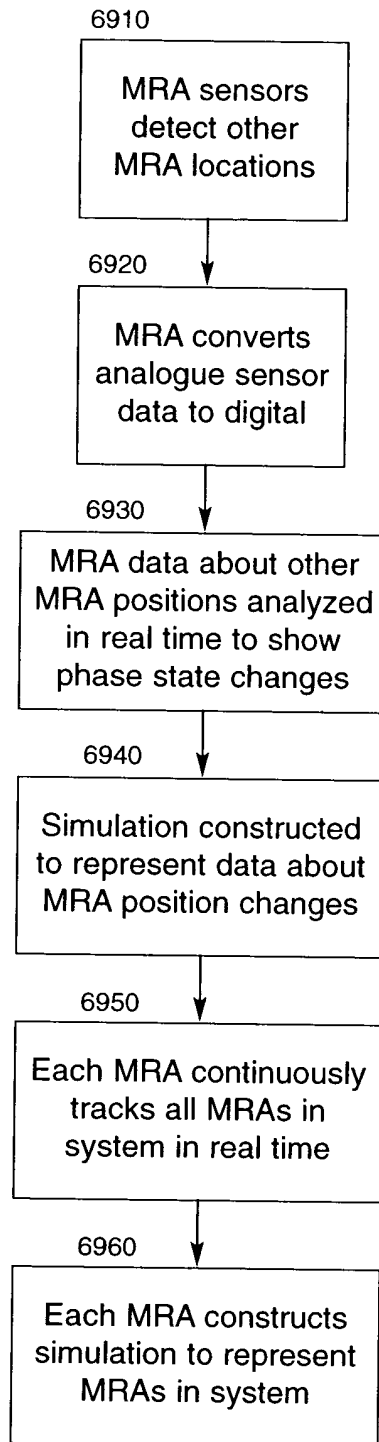


Fig 70: Contingency CA Scenario Option Simulations

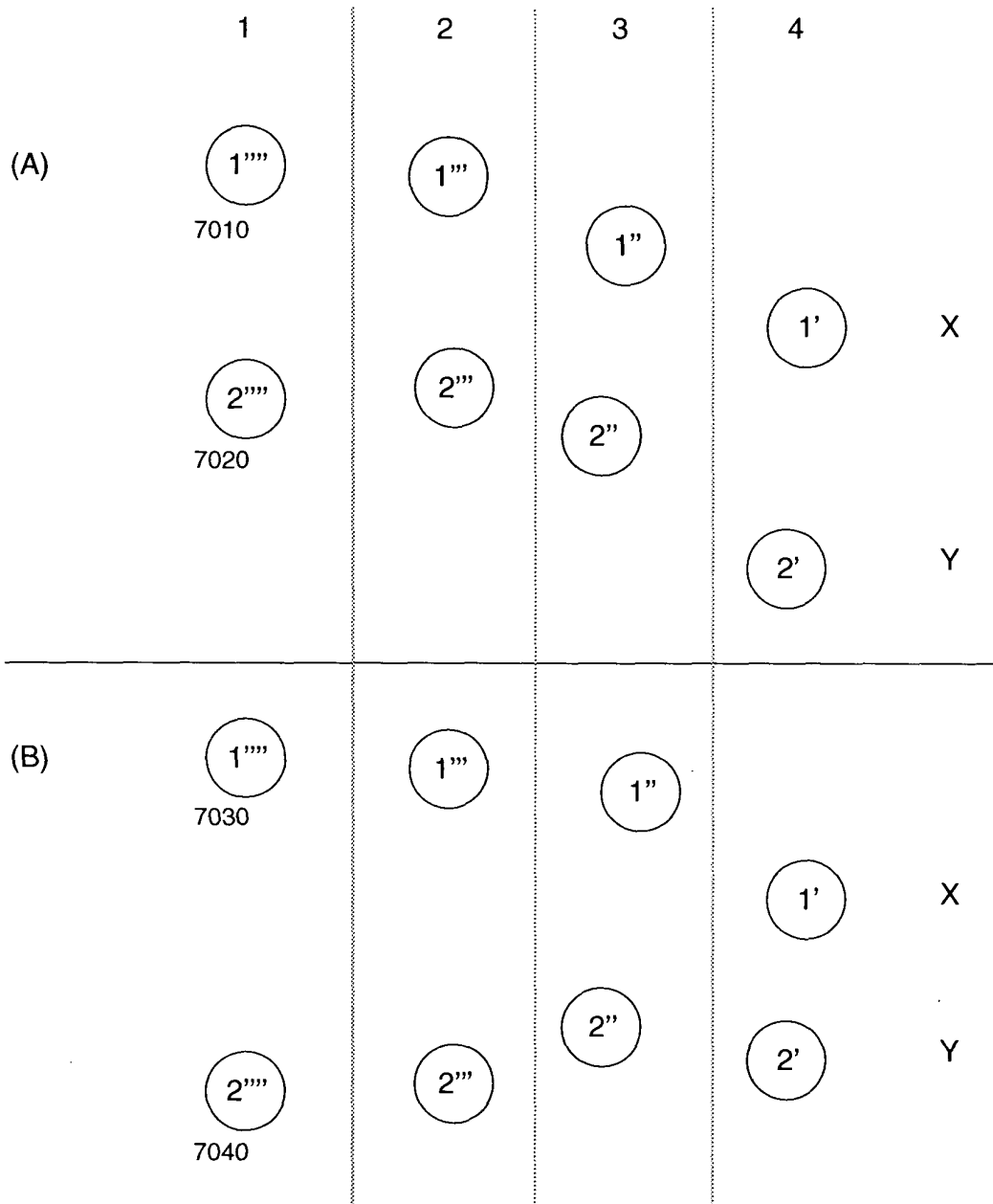


Fig 71: Reversible (Deterministic) CA-Projecting Backwards From A Goal

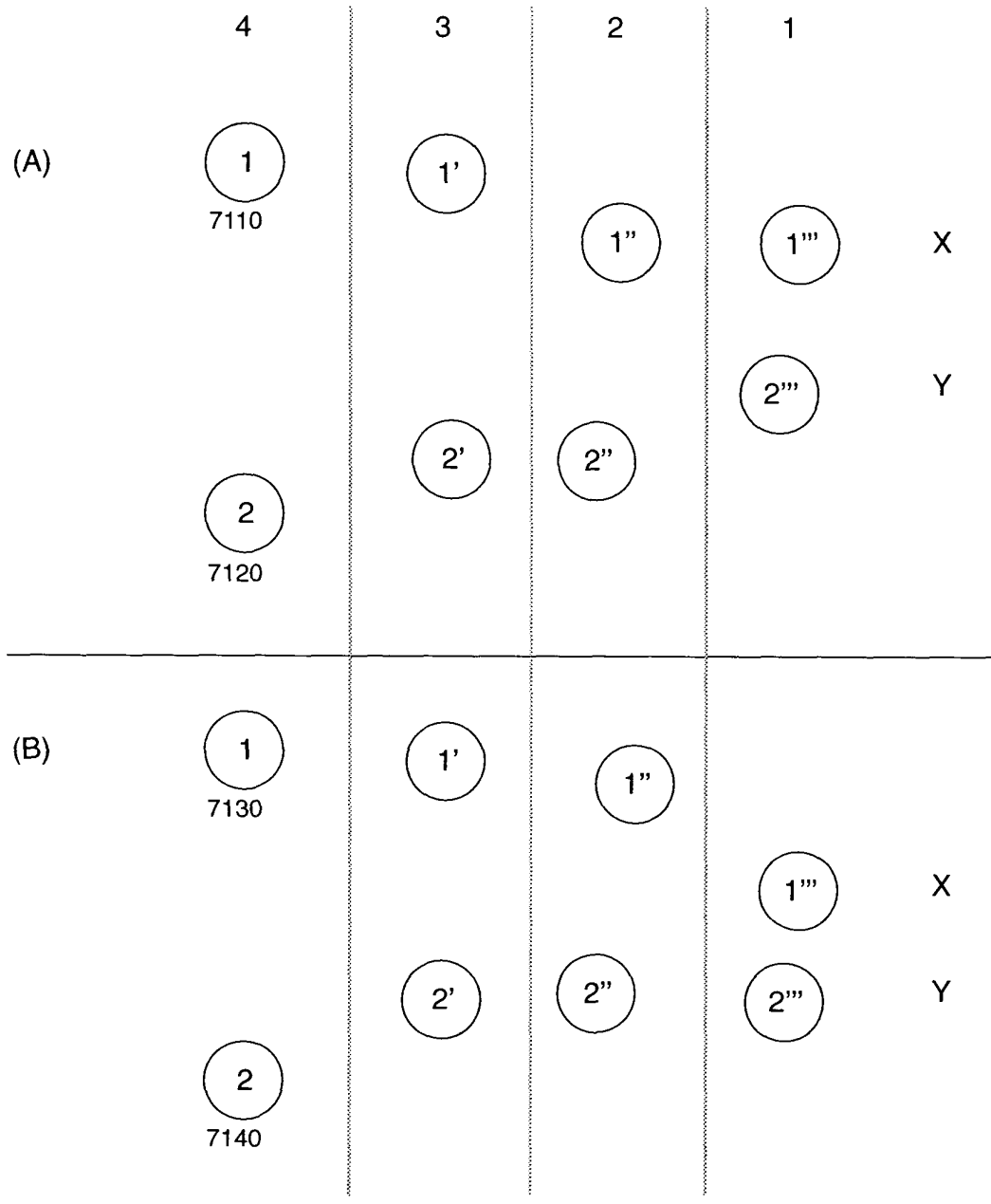
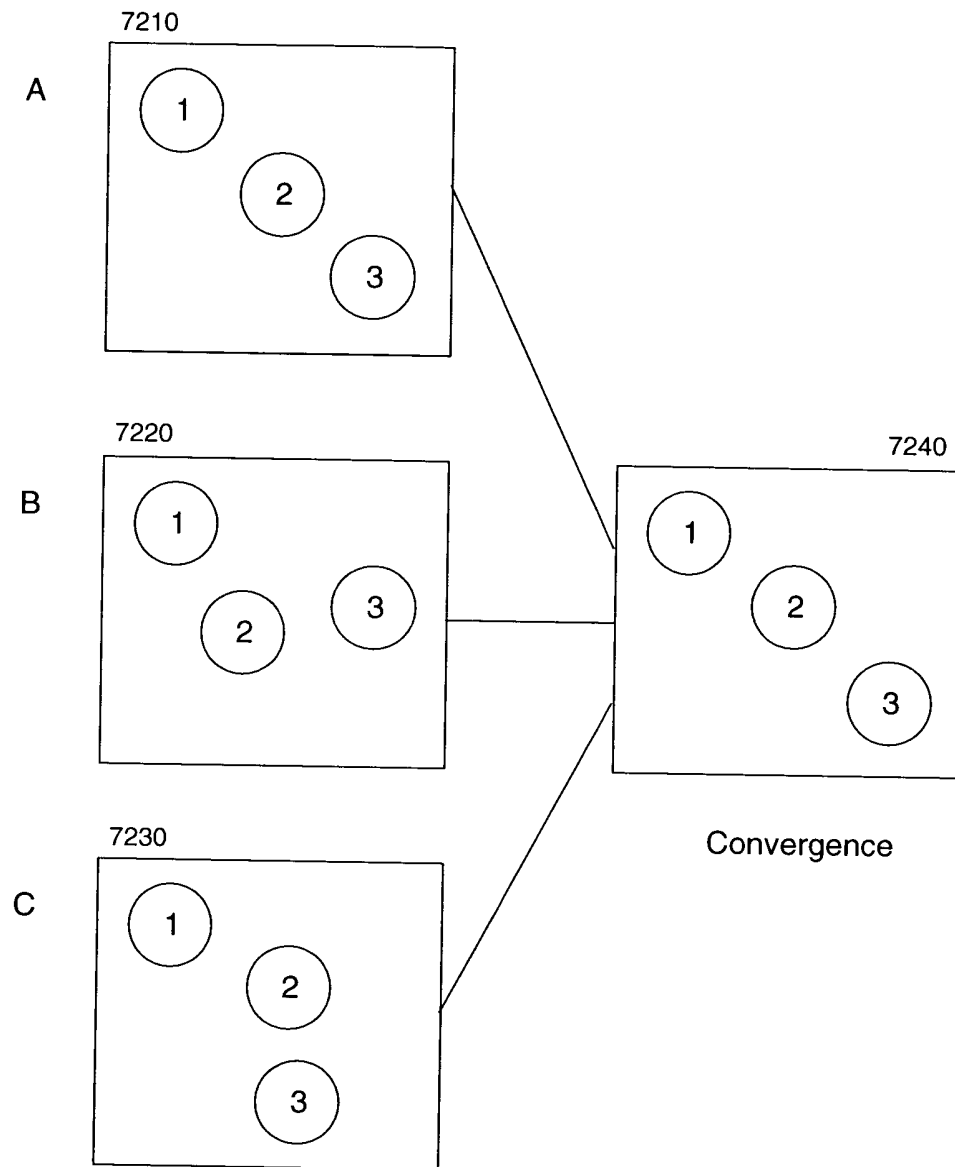
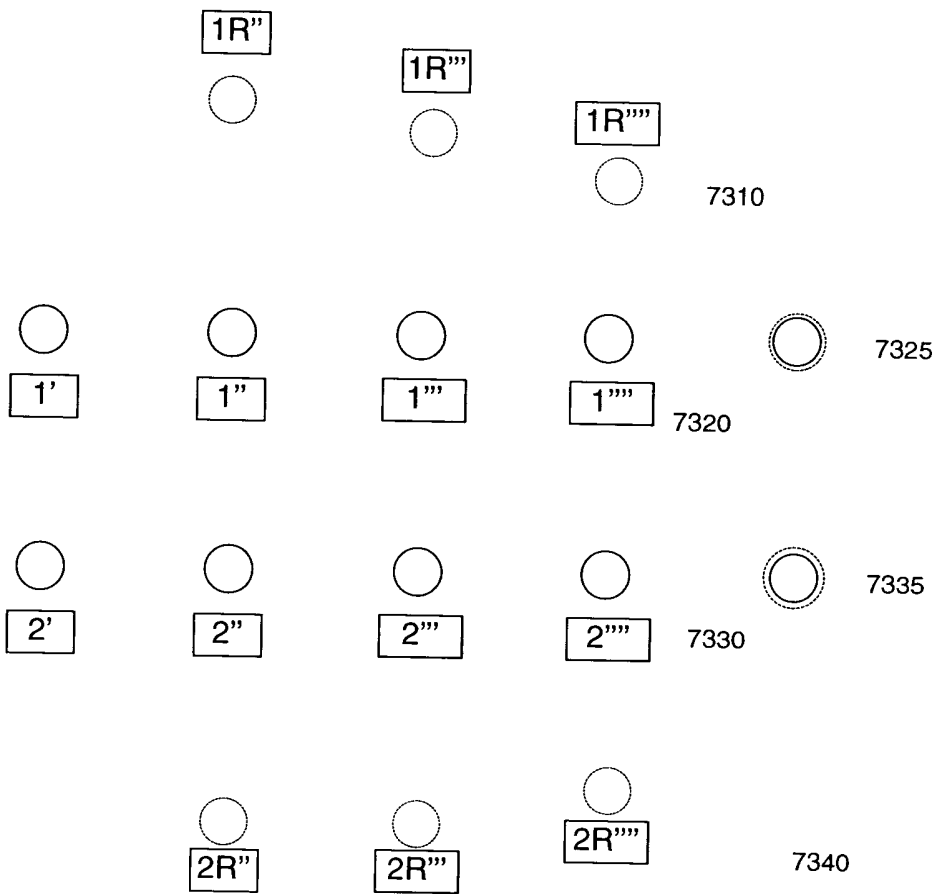


Fig 72: Adaptive Geometric Set Theory Applied To MRS



**Fig 73: Selecting Optimal Simulation-
(Temporary) Convergence of Simulation Scenarios**



**Fig 74: Initiation of Aggregation Process -
Sets of MRAs Forming From Larger Collective**

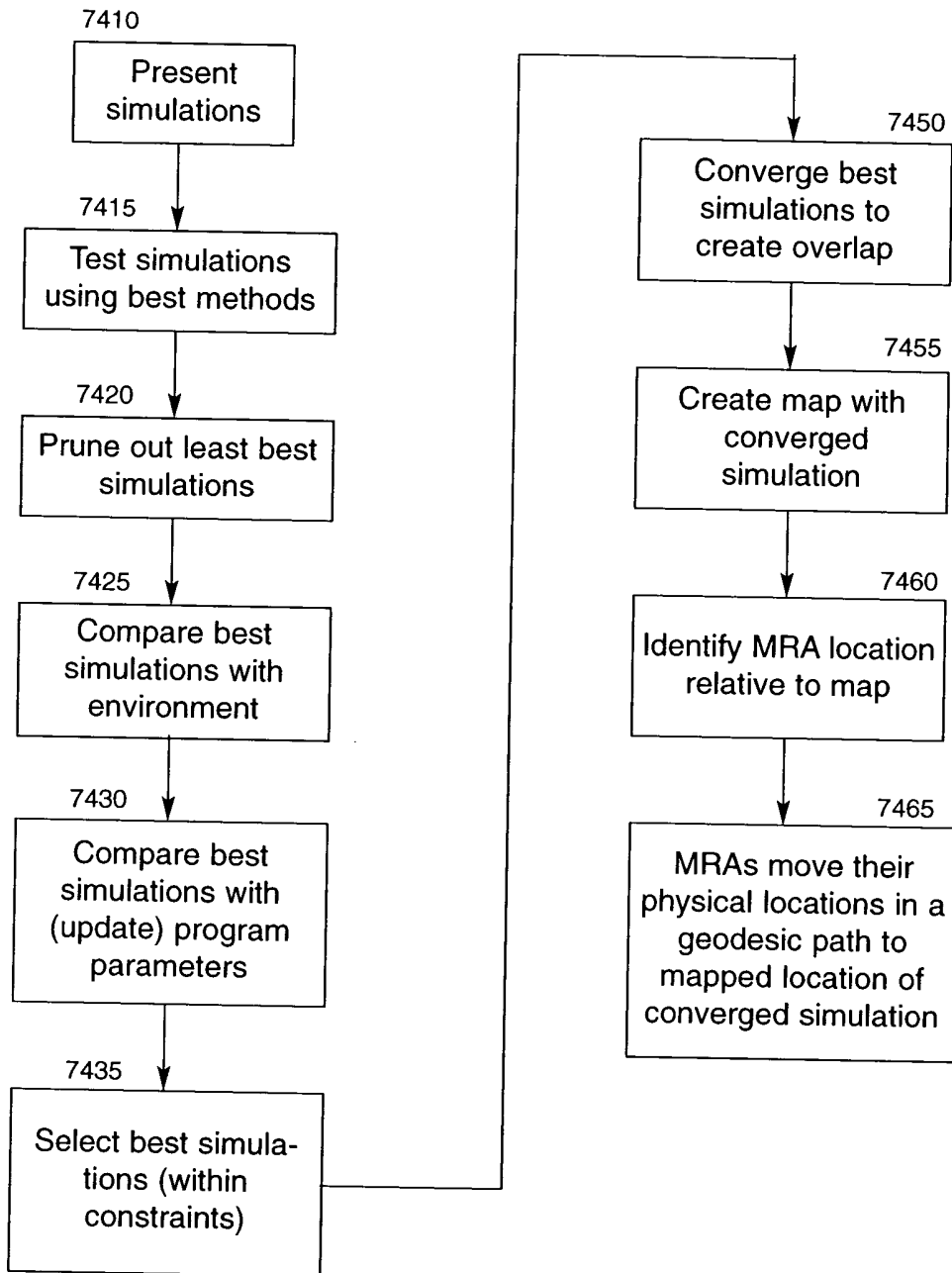


Fig 75: Initiating Homogeneous MRA Group Formation

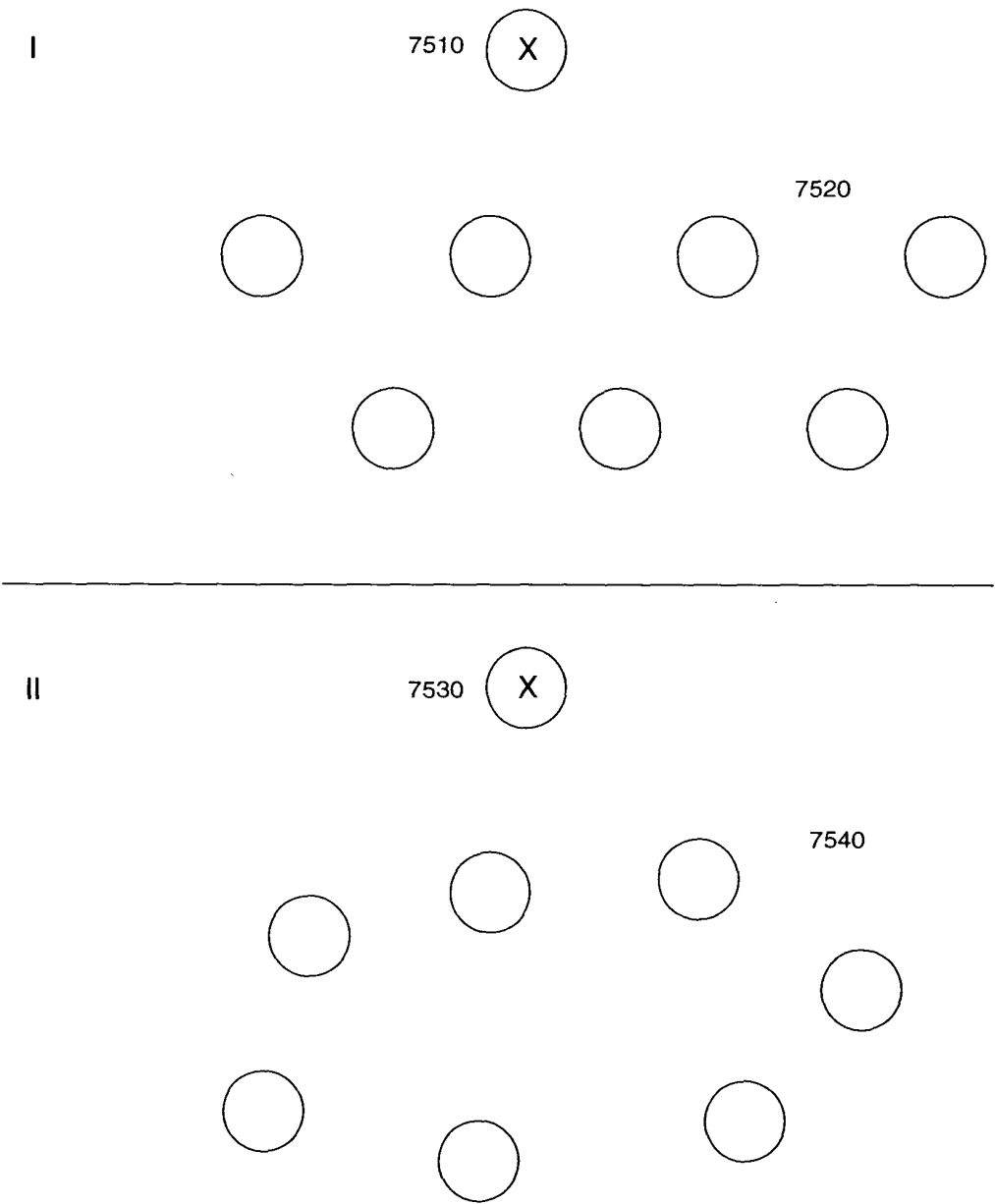
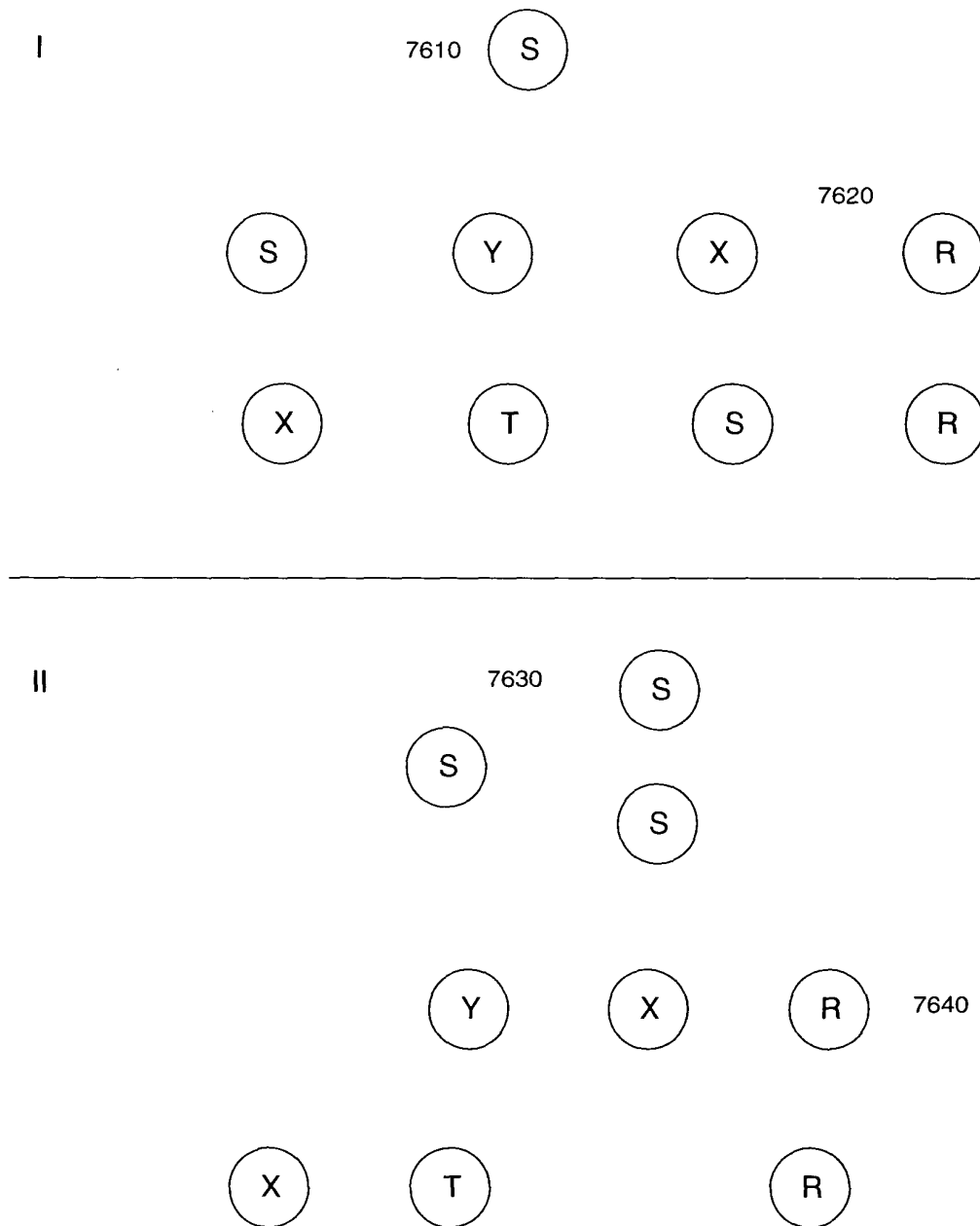


Fig 76: Initiating Common Heterogeneous MRA Group Formation



**Fig 77: Initiating Complementary Heterogeneous
(Specialized) MRA Group Formation**

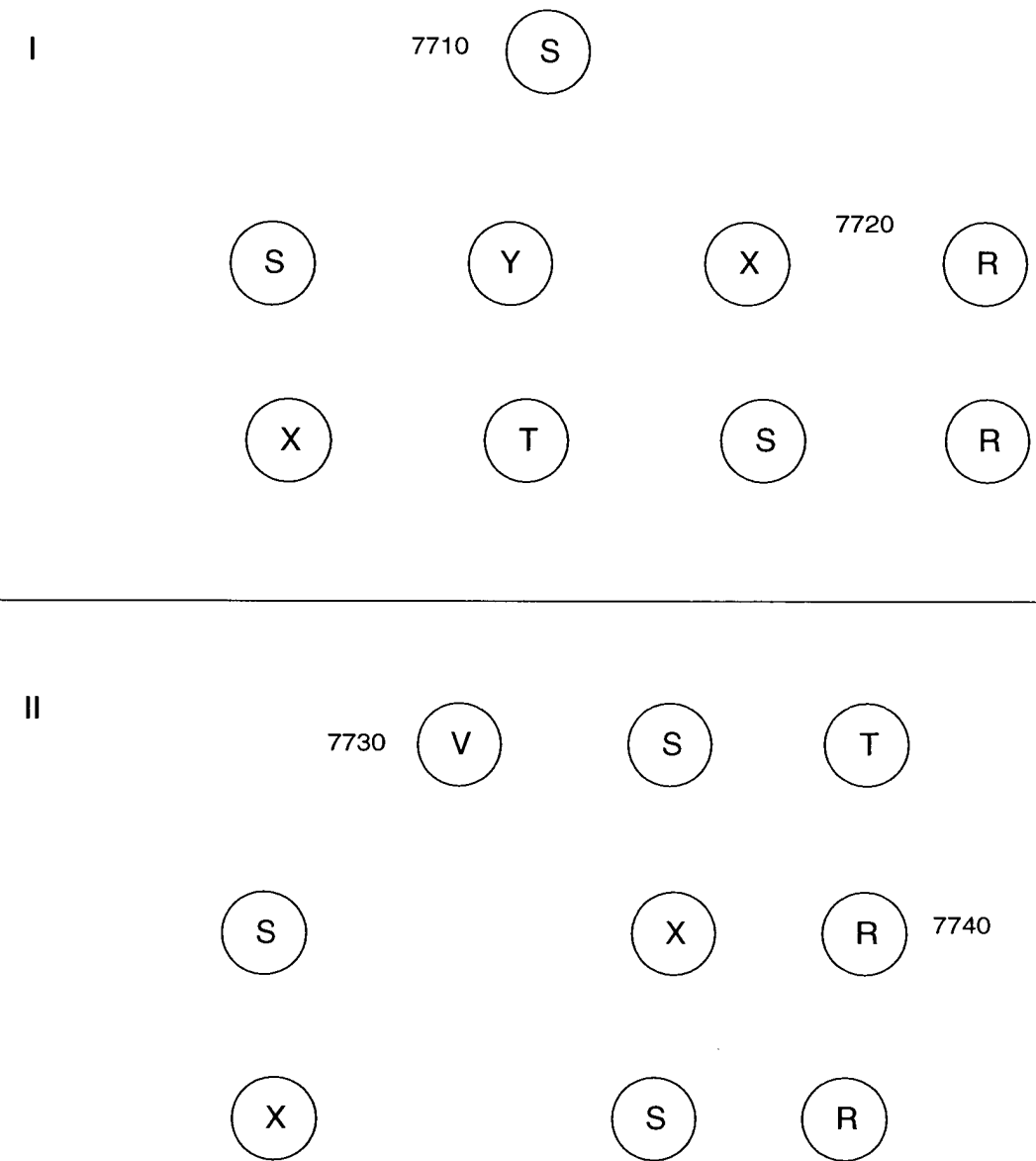


Fig 78: Demand Initiated Environmental Adaptation: Initial Phase

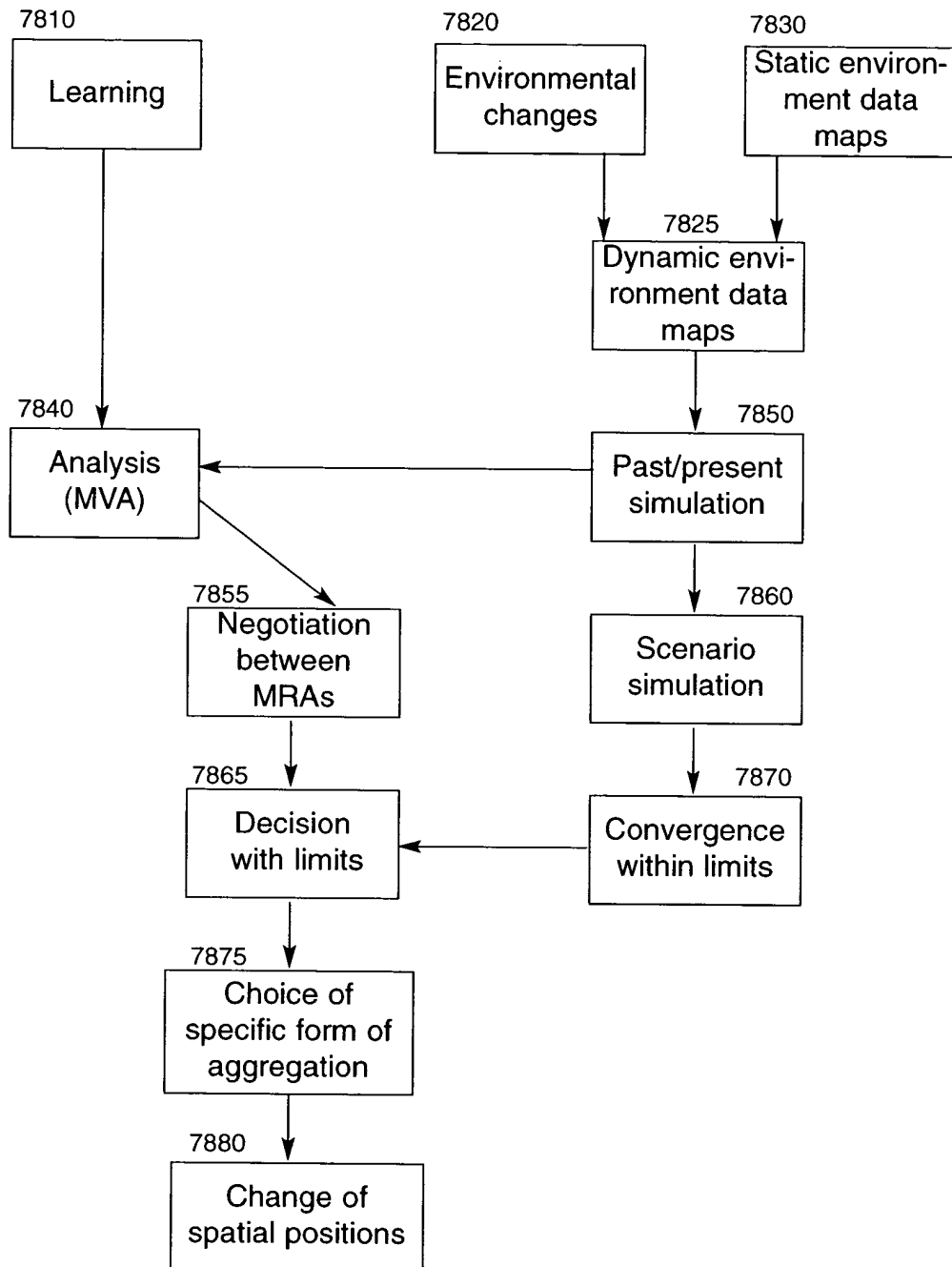
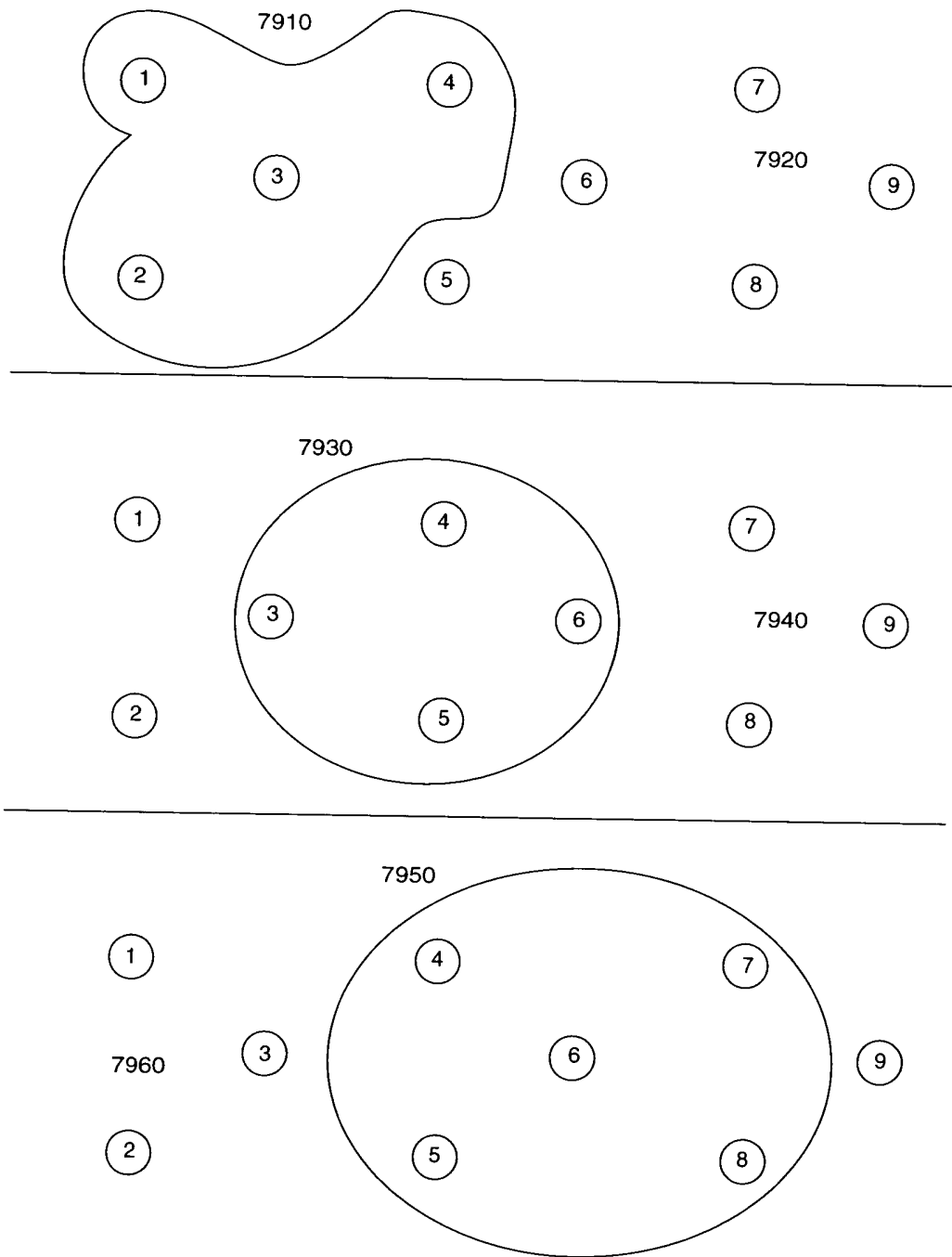
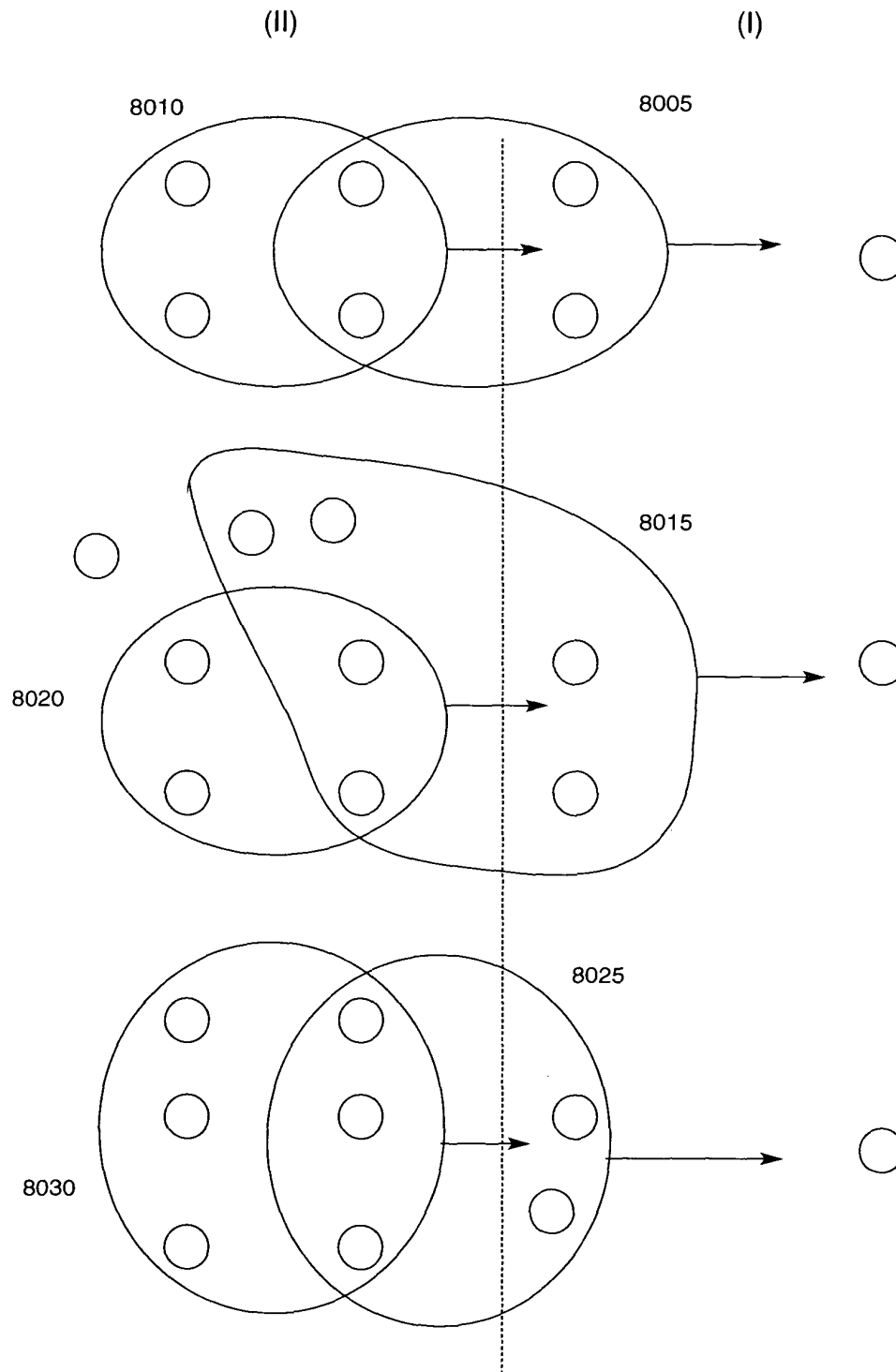


Fig 79: Continuous MRA Group Composition Reconfiguration



**Fig 80: Continuous Reconfiguration of Sub-networks
(Scalable Capacity Increases and Decreases)**



**Fig 81: Dynamic Group Behavior Adaptation
to Environmental Interaction**

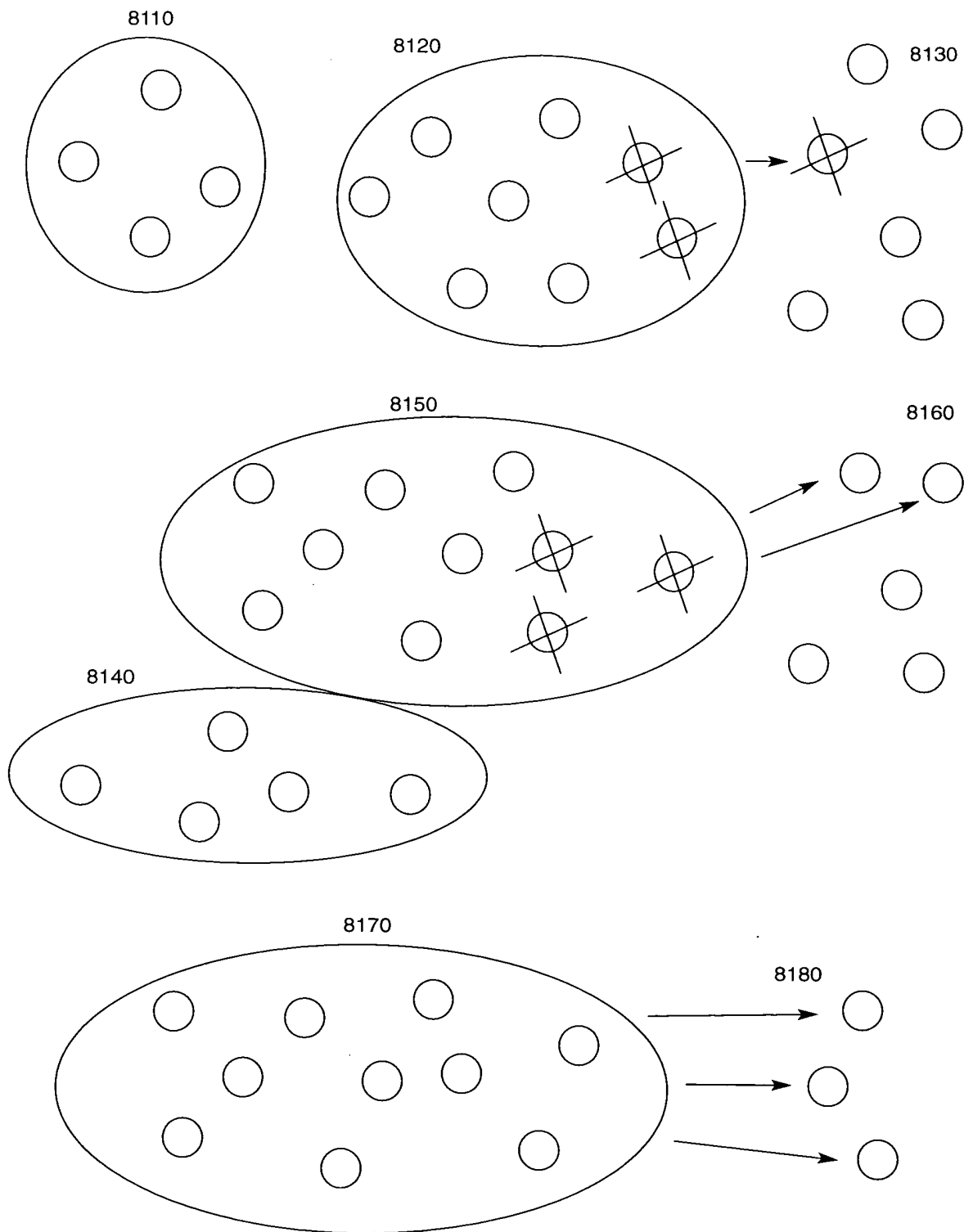


Fig 82: Parallel Dynamic Traveling Salesman with Cooperating Autonomous Agents

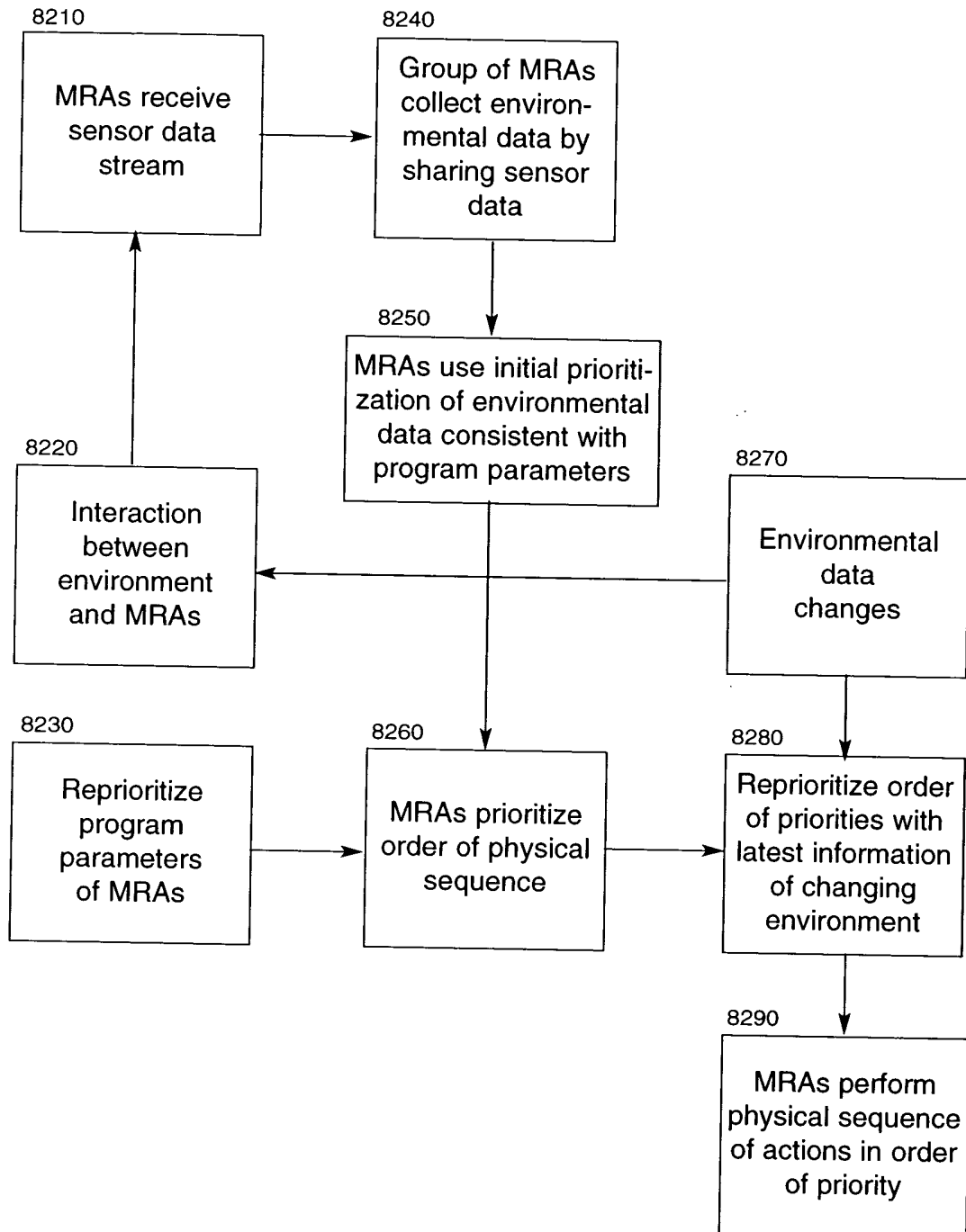


Fig 83: Sacrificing (Altruistic) MRAs in Order to Acquire Sensor Information to Increase Chances of Overall Mission Success

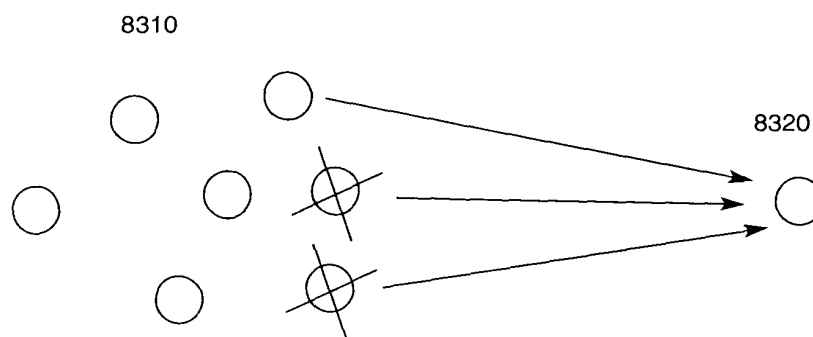


Fig 84: General Dynamic Coalition Process

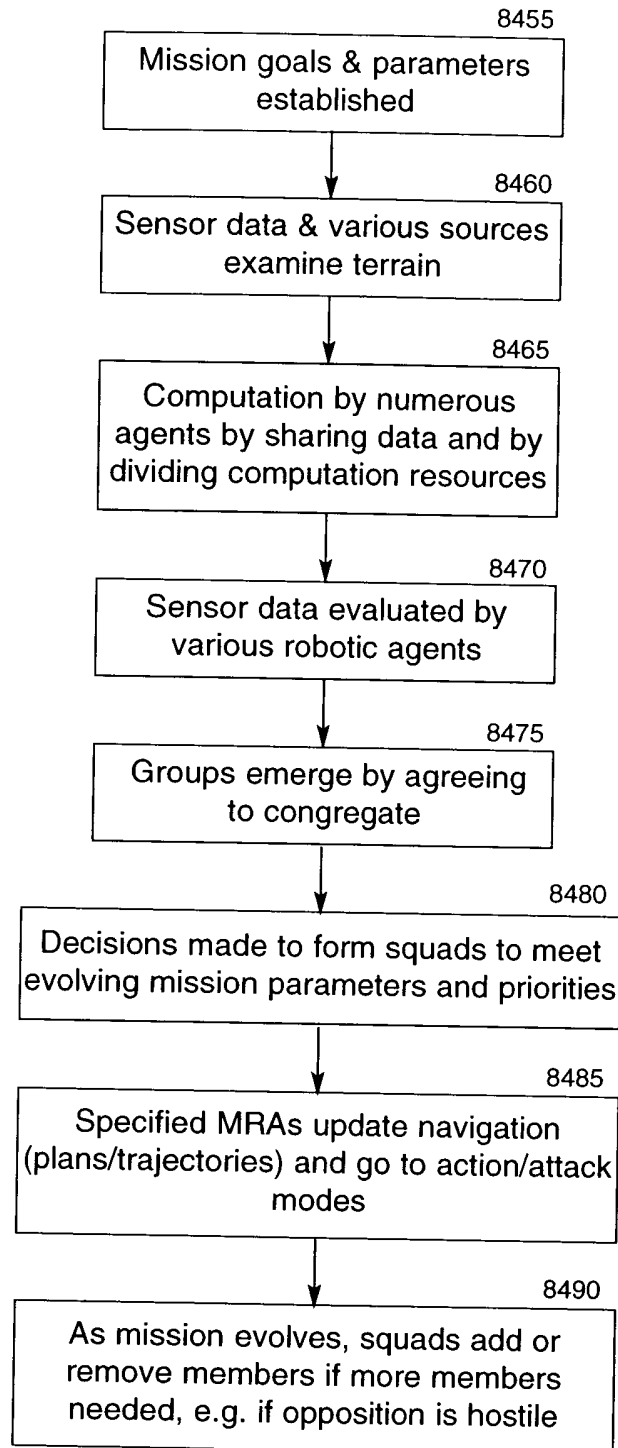


Fig 85: Group Coordination and Obstacle Avoidance

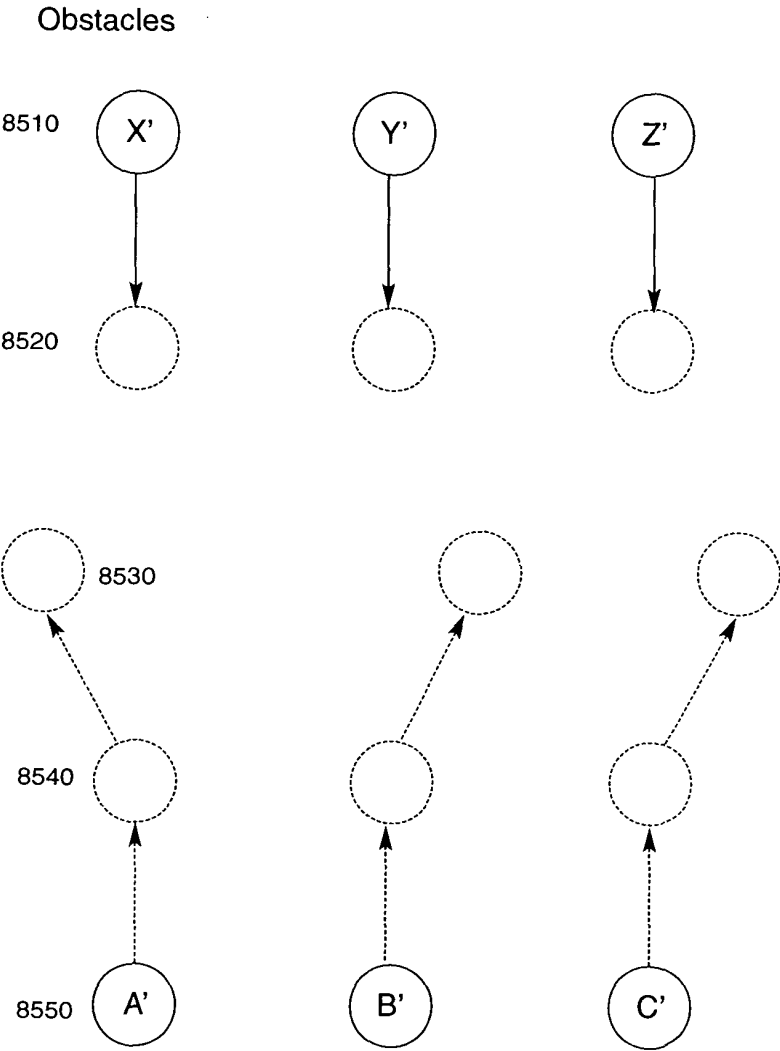


Fig 86: Specialization: Specific MRA Functionality

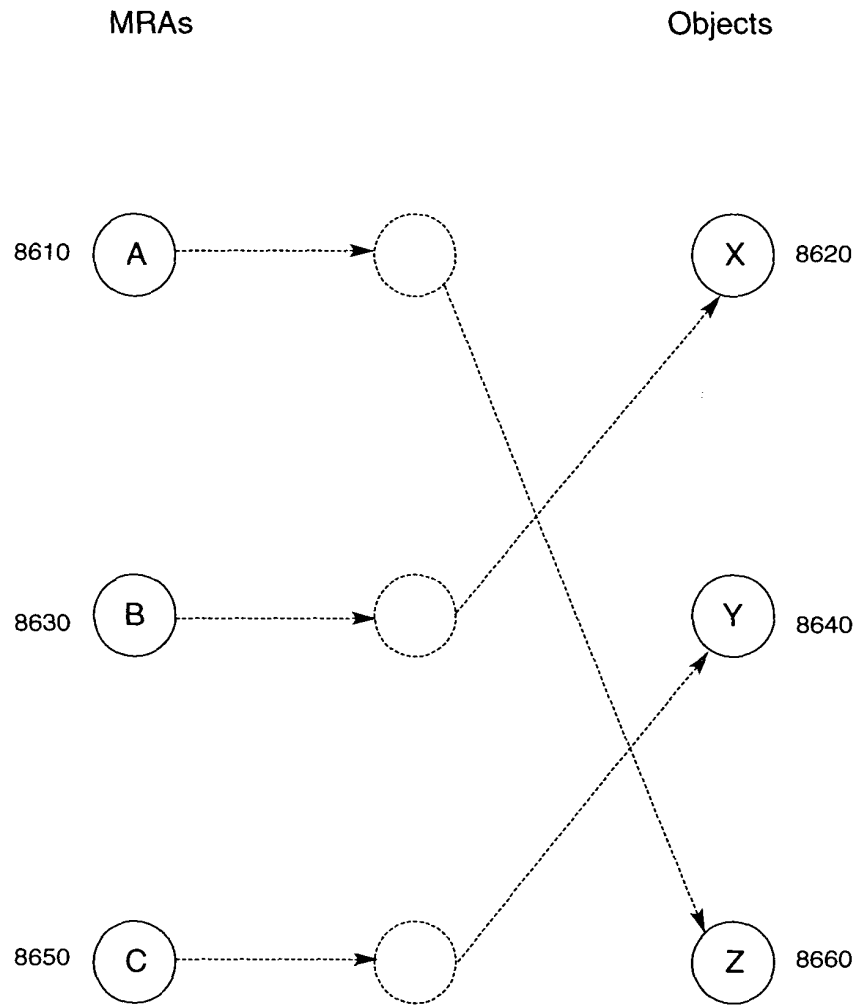


Fig 87: Specialized MRAs Working As A Team

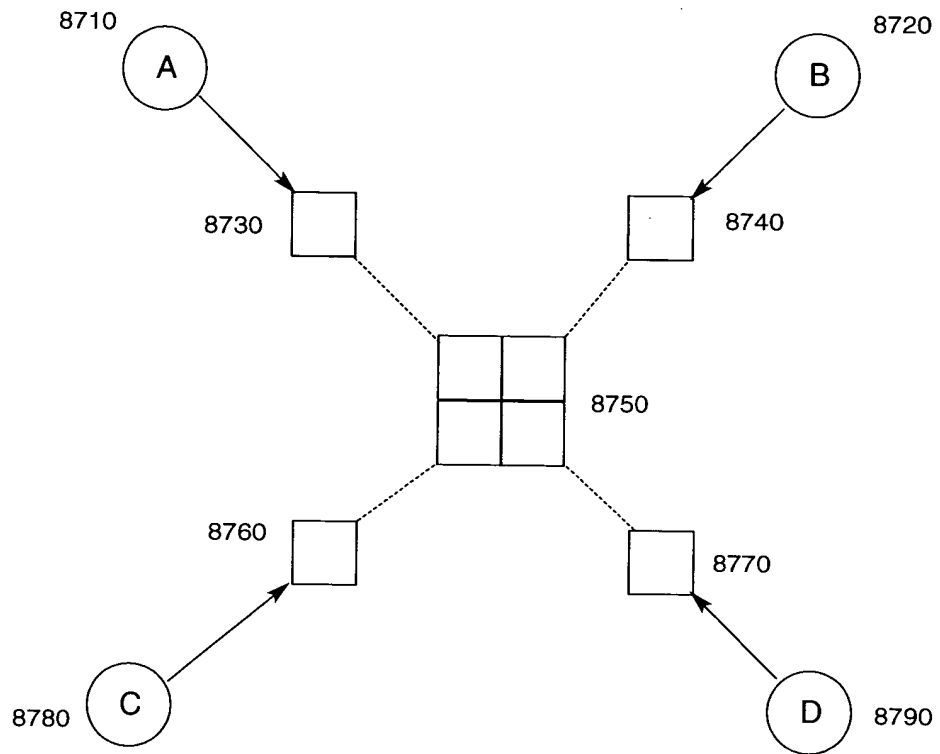
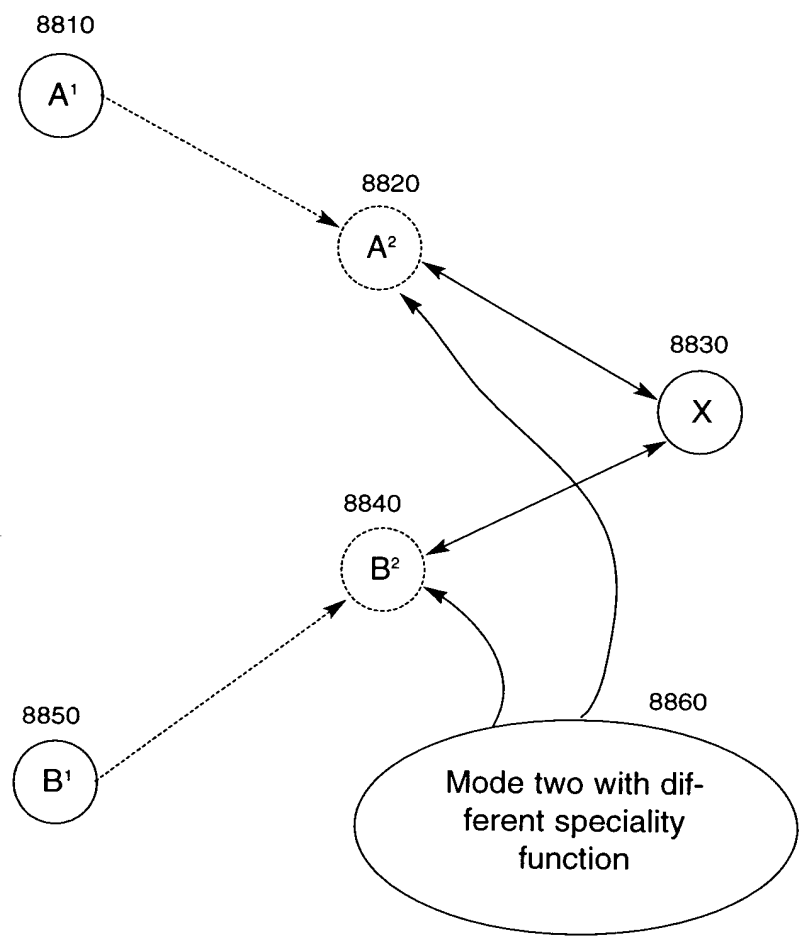
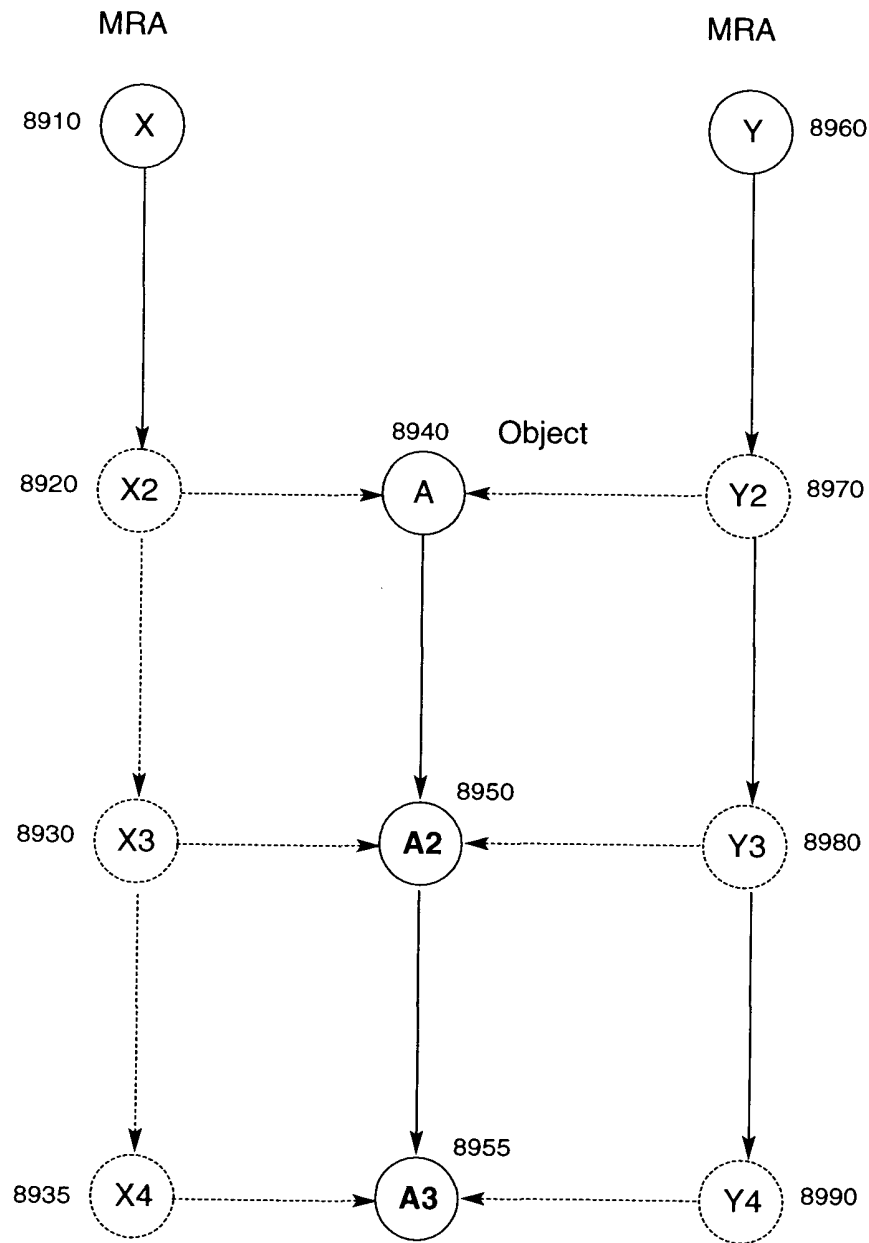


Fig 88: Multi-functional MRAs in Self Organizing Process



**Fig 89: Surveillance & Reconnaissance - Mobile Object
Sensed & Tracked By Multiple Micro-MRAs**



**Fig 90: Remote Exploration: Initial Tracking of Multiple Objects
With Multiple Micro-MRAs**

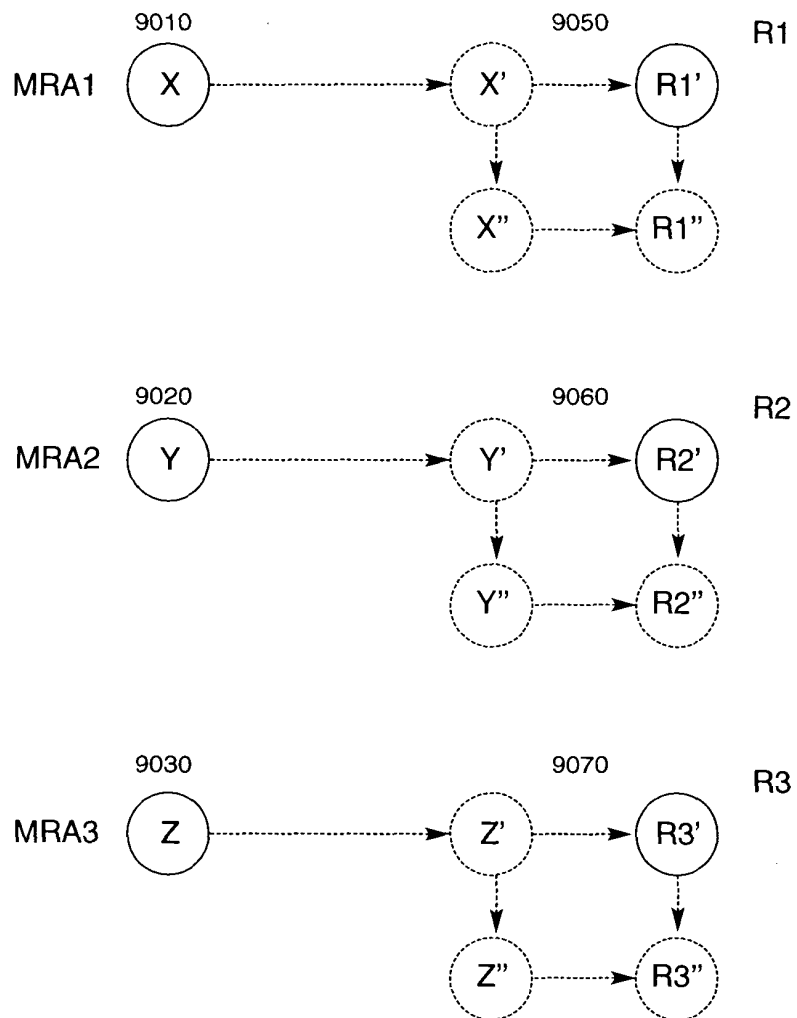


Fig 91: Sentry Action - Limited Perimeters - Defending Multiple Objects With Multiple MRAs

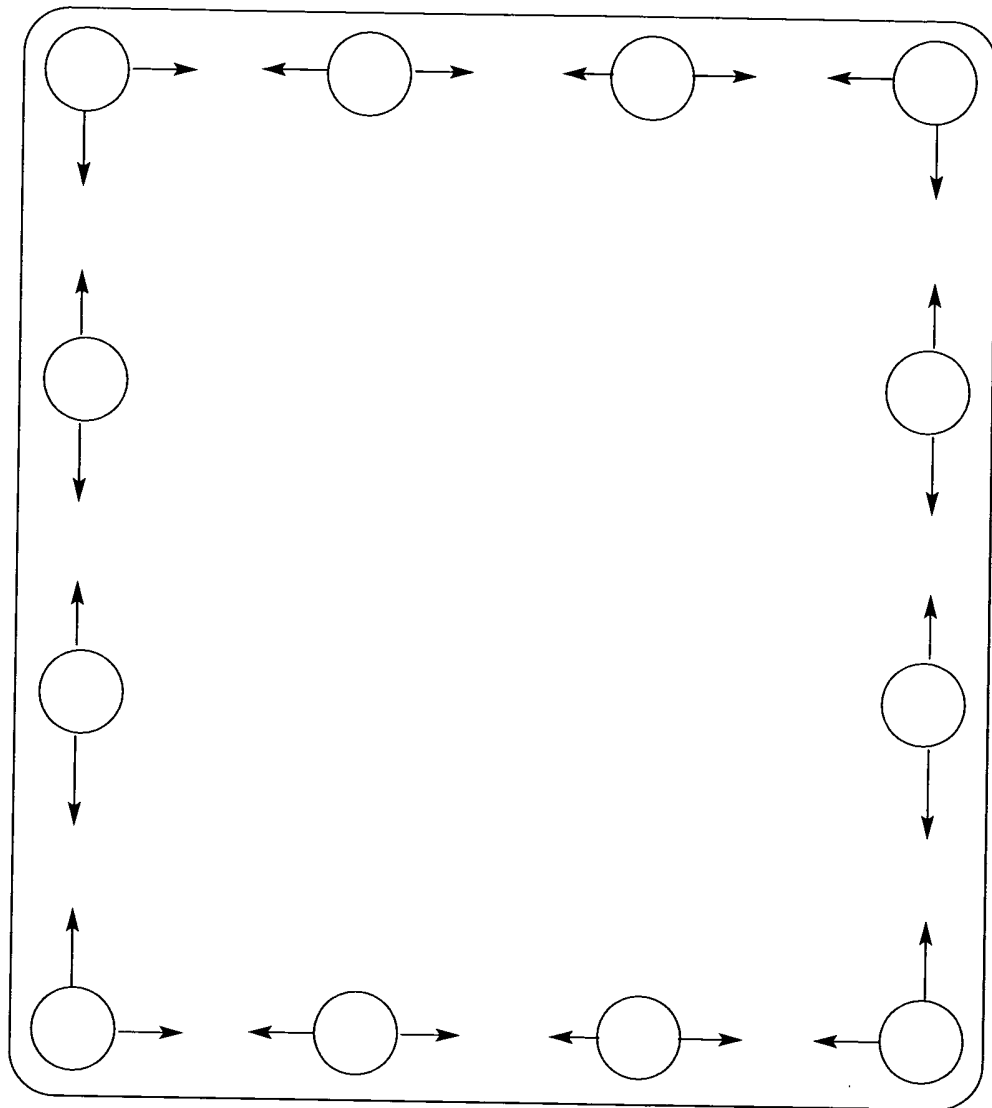
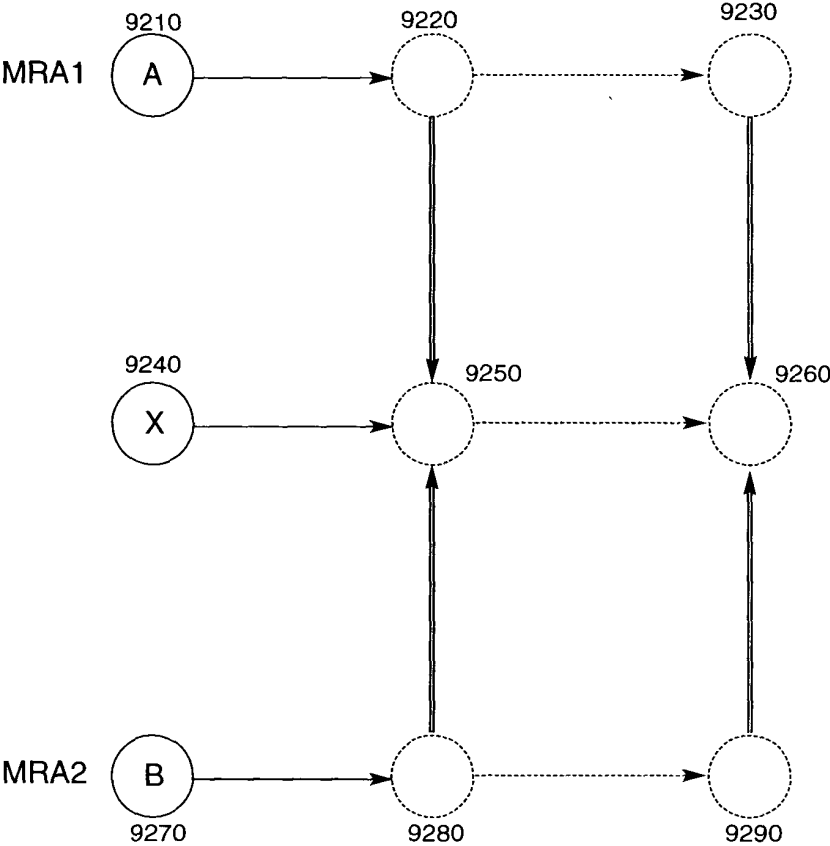


Fig 92: Cinematography - One Mobile Object (or Cluster of Mobile Objects) Sensed and Tracked with MRAs



**Fig 93: Toxic Site Cleanup - Static Cleanup
Within Land Perimeters by Multiple MRAs**

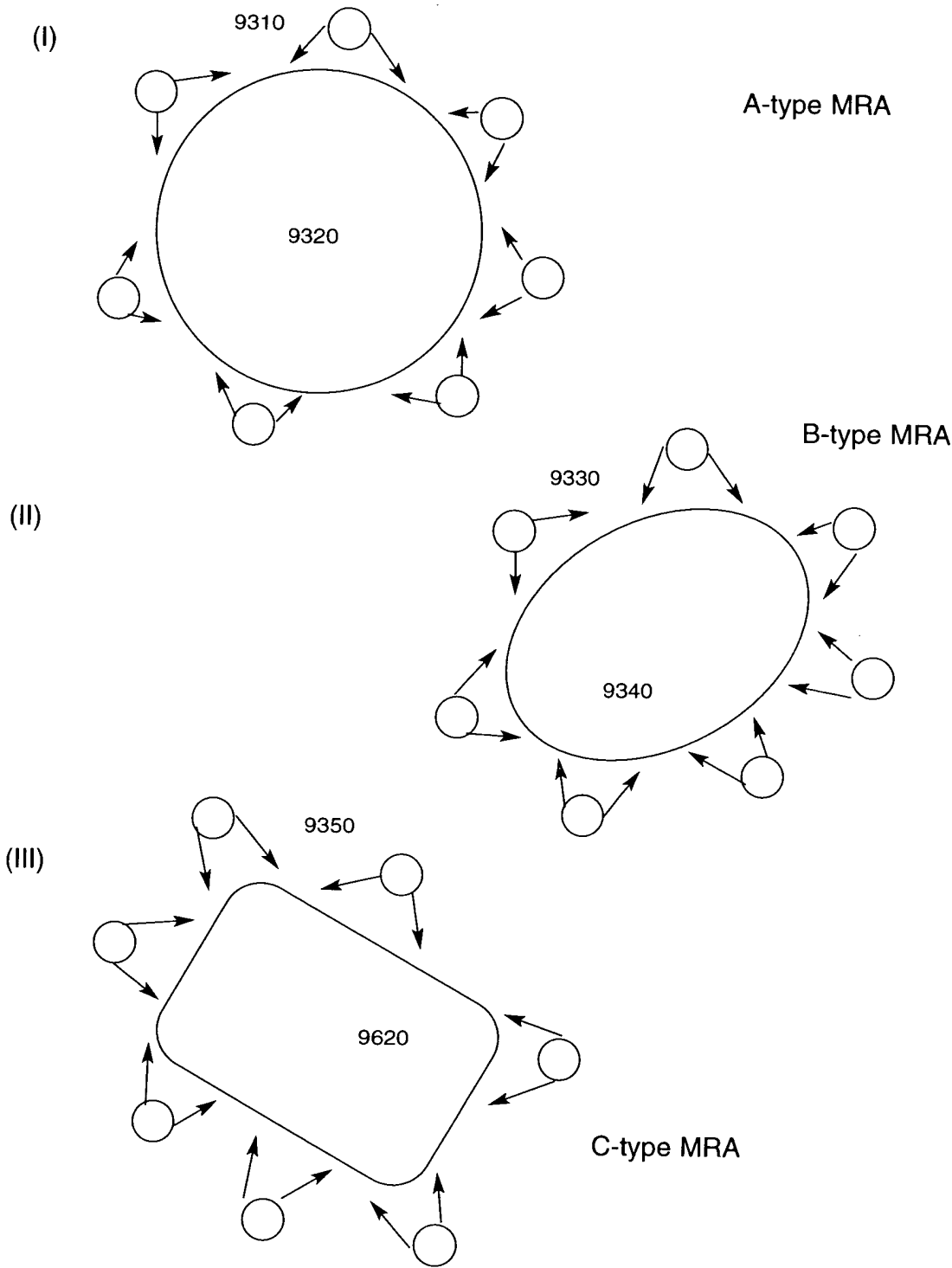
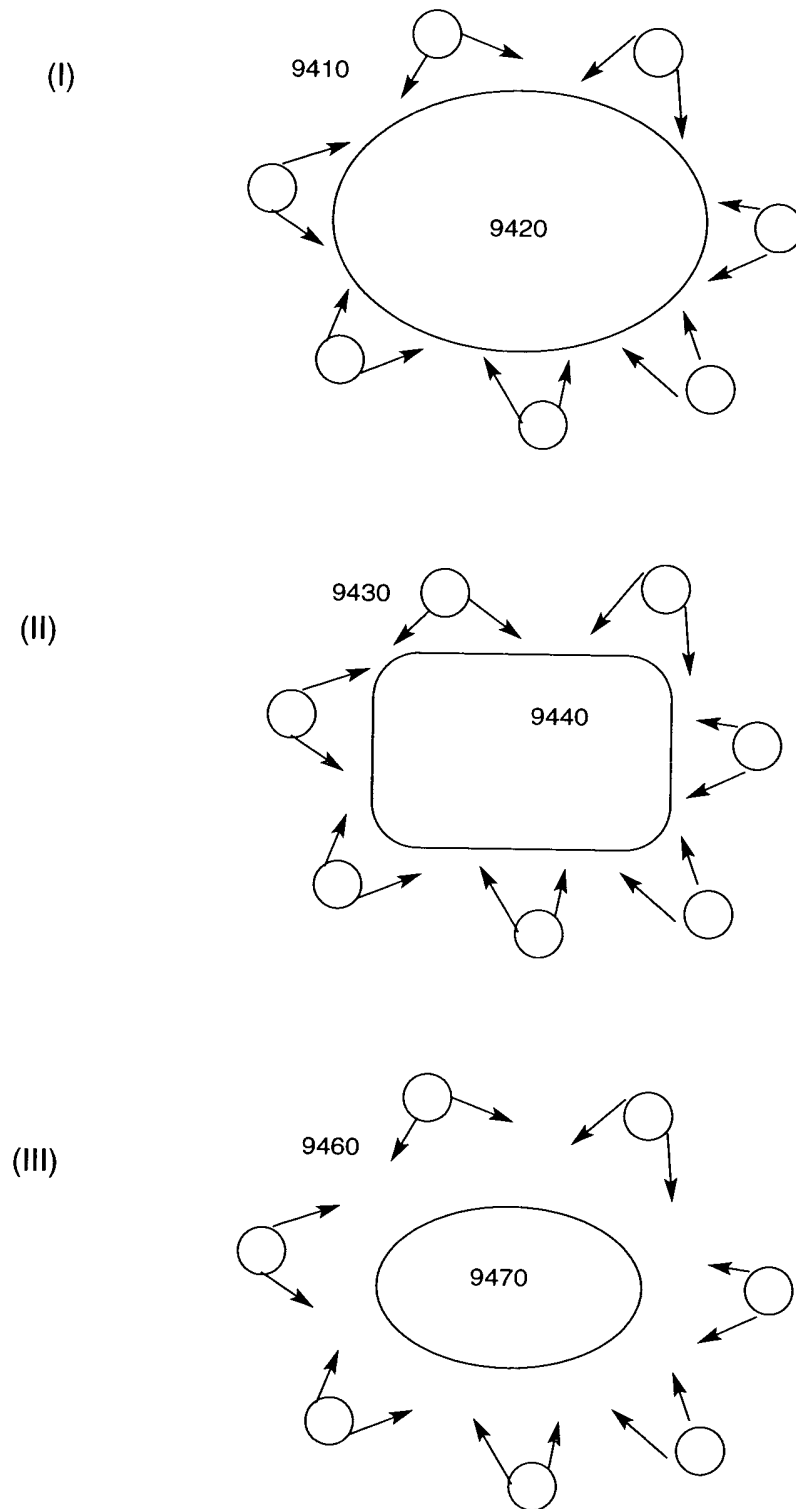
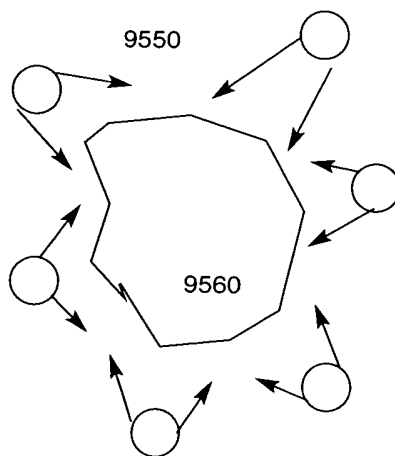
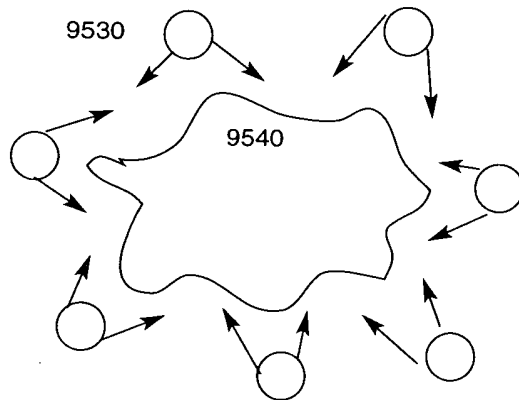
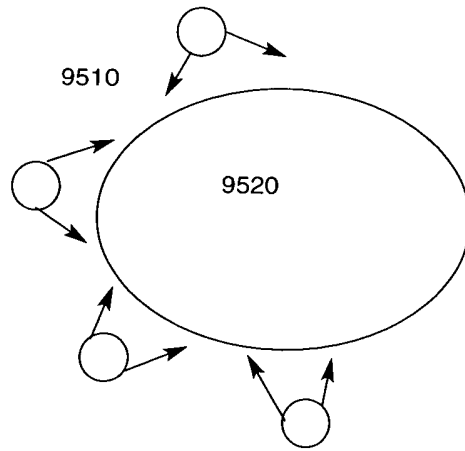


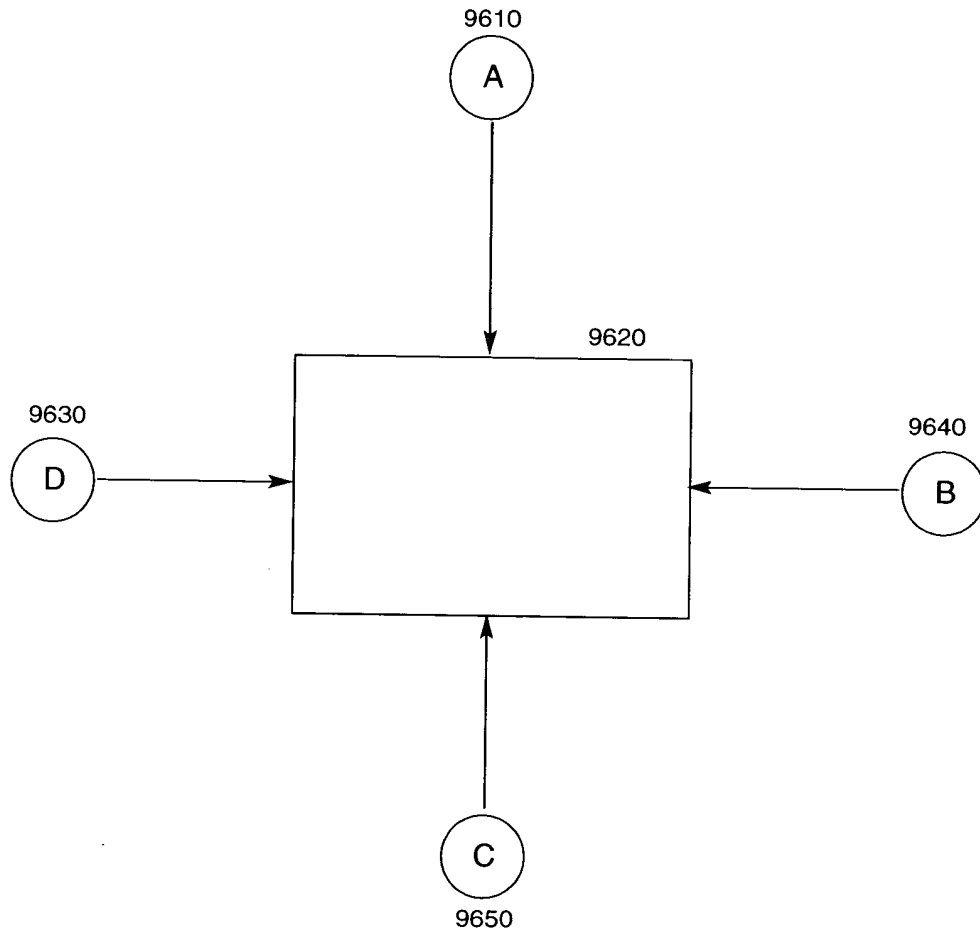
Fig 94: Oil Spill: Dynamic Cleanup Within Limited Hydro Perimeters by Multiple MRAs



**Fig 95: Fir Fighting - Dynamic Interaction
With Complex Environment by Multiple MRAs**



**Fig 96: Manufacturing Production:
Object Creation Using Multiple MRAs**



**Fig 97: Assembly: Combining Parts To Create
Whole Object Using Multiple MRAs**

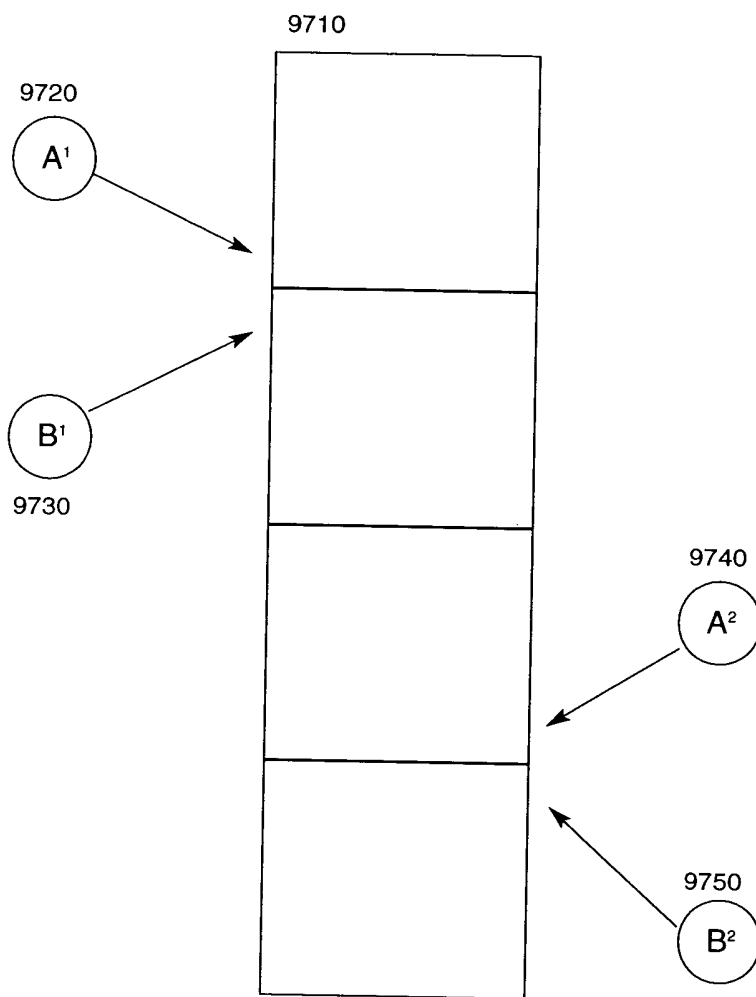


Fig 98: Building Roads: Road Creation Using Multiple MRAs

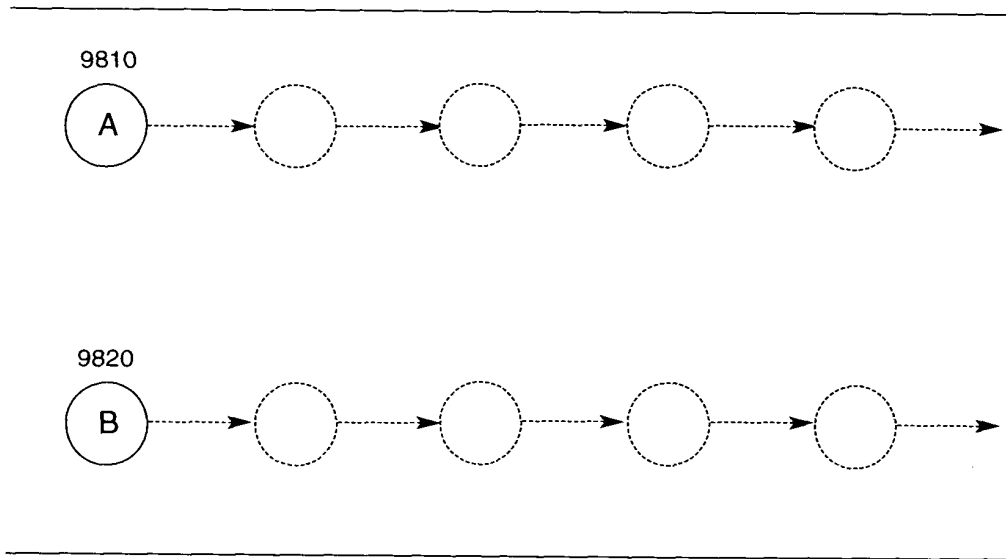


Fig 99: Surgical Micro MRAs for Trauma Intervention & Stabilization

